A Mass Balance Model of the Newfoundland-Labrador Shelf

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Abstract

Bundy, Alida, George R. Lilly, and Peter A. Shelton. 2000. A mass balance model of the Newfoundland-Labrador Shelf. Can. Tech. Rep. Fish. Aquat. Sci. 2310: xiv + 157 p.

A mass balance model using the Ecopath approach was constructed for the southern Labrador Shelf, Northeast Newfoundland Shelf and Grand Bank in Northwest Atlantic Fisheries Organisation (NAFO) Divisions 2J+3KLNO for the period 1985-1987. The exercise effected a synthesis of information on biomass, consumption, production and diet of major species or species groups. The paucity of data on biomass and diet of many groups was emphasised. Information on productivity of lower trophic levels was especially weak. Major imbalances were found in the original model. Biomass estimates of some prey species were increased substantially to meet the food requirements of predators. Hooded seals were at the top of the food web. Other high level predators included Greenland halibut, harp seals, Atlantic cod and skates. The major predators in the area were harp seals and Atlantic cod. The dominant planktivorous fish was capelin, but Arctic cod and sand lance were also important.

Résumé

Bundy, Alida, George R. Lilly, and Peter A. Shelton. 2000. A mass balance model of the Newfoundland-Labrador Shelf. Can. Tech. Rep. Fish. Aquat. Sci. 2310: xiv + 157 p.

Un modèle de bilan massique fondé sur l'approche Ecopath a été établi pour le sud du plateau continental du Labrador, le nord-est du plateau continental de Terre-Neuve et la partie des grands bancs située dans les divisions 2J+3KLNO de l'Organisation des pêches de l'Atlantique Nord-Ouest (OPANO) pour la période 1985-1987. L'exercice comportait une synthèse de renseignements sur la biomasse, la consommation, la production et l'alimentation des principales espèces ou des principaux groupes d'espèces. Il a mis en évidence le manque de données sur la biomasse et sur l'alimentation de nombreux groupes. On a relevé d'importants déséquilibres dans le modèle original. Les estimations de biomasse de certaines espèces-proies ont été augmentées notablement, en fonction des besoins alimentaires des prédateurs. Les phoques à capuchon occupaient le sommet du réseau trophique. Parmi les autres prédateurs de haut niveau, citons le flétan du Groënland, le phoque du Groënland, la morue et les raies. Dans la région, les grands prédateurs étaient le phoque du Groënland et la morue. Le principal poisson planctivore était le capelan, mais la morue arctique et le lançon occupaient aussi une place importante.

Introduction

Mass-balance biomass models are being used globally as an efficient and useful method to systematise ecosystems and explore their properties (Christensen and Pauly 1993; Christensen 1995; Pauly and Christensen 1996). They represent the complexity of an ecosystem in a relatively simple way and are useful as a diagnostic tool. Christensen and Pauly (1993) describe three main benefits of the models: (i) they require researchers to review and standardise all available data on a given system; (ii) they identify states and rates which are mutually incompatible; and (iii) they bring together species specialists and modellers in a collaborative exercise. A fourth benefit is that the approach can highlight knowledge gaps in systems that are considered relatively well studied.

The model presented in this paper originated in a workshop that was held at the Northwest Atlantic Fisheries Centre, St. John's, NF, Canada 14-22 October 1993. Several experts from DFO and the Memorial University of Newfoundland gathered at this meeting with the aim of constructing a steady-state box model for the shelf system off Labrador and eastern Newfoundland. The workshop, structured around the ECOPATH approach of Polovina (1985, ECOPATH I) and Christensen and Pauly (1992, ECOPATH II), benefited from the advice of Dr. V. Christensen (ICLARM, Manila, Philippines), whose participation was supported in part by the Northern Cod Science Program.

The choice of study area involved compromise. For biological reasons, it may have been appropriate to choose areas corresponding to physiographic regions such as the Labrador Shelf, the Northeast Newfoundland Shelf and Grand Bank (Fig 1a), because species composition within the regions is likely to be more homogeneous than among regions. Groundfish assemblages, such as those described by Gomes *et al.* (1992, 1995), may have provided guidance. However, it was also convenient to choose boundaries coinciding with Northwest Atlantic Fisheries Organisation (NAFO) Divisions (Fig. 1b) because commercial fishery statistics are of great importance to the model and are often not available at spatial scales smaller than Division. The first problem with choosing boundaries is that physiographic boundaries and Division boundaries do not coincide. This is most notable in Division 3L, which straddles the boundary between the Northeast Newfoundland Shelf and Grand Bank.

A second consideration in choice of study area was finding contiguous Divisions which corresponded to stock boundaries for the majority of important commercial species. This was considered important because much of the data for commercial species, including population estimates from sequential population analyses, are organised by stock. This consideration also proved difficult to meet (Fig. 2). The largest and most important stock in the area was 2J+3KL cod, which has its southern boundary across the centre of Grand Bank. However, several other important stocks, most notably 3LNO American plaice, have their northern stock boundary just north of Grand Bank. It was awkward, then, to place a boundary at either the 3K/3L line or the 3L/3NO line. With respect to the northern boundary of the study area, several stocks extend to the tip of Labrador, but for some of these stocks the bulk of the biomass occurs south of the 2H/2J boundary. Furthermore, there have been few research surveys north of Division 2J. It seemed reasonable to place the northern boundary at the 2H/2J line. At the southern end of the range, none of the important species have stocks that overlap with Subdivision 3Ps, so the 3O/3Ps boundary was taken as the southwestern limit. Flemish Cap (Division 3M) was readily eliminated, because most species occurring on the Cap have stocks that are clearly distinct from those on the adjacent Grand Bank. Greenland halibut, a deepwater species, is an important exception. For the above reasons, it was felt that the study area should be Divisions 2J+3KLNO (the southern third of the Labrador Shelf, the Northeast Newfoundland Shelf and Grand Bank) from the coast out to the 1,000 m isobath, a total area of about 495,000 km^2.

Because the study area is large and spread across three physiographic regions, there are numerous difficulties with assessing the degree of interaction among the various species. Some species (e.g. haddock, white hake) tend to be associated with the relatively warm water of the southwestern Grand Bank, and tend to interact very little with species north of the 3L/3NO boundary. Other species, such as Greenland halibut and sand lance, tend not to interact with one another because they have different depth requirements. Seasonal migrants are important to the model. Harp and hooded seals and certain birds come into the area from the north in late autumn and remain until spring whereas most whales, many birds, some fish (e.g. mackerel) and short-finned squid come into the area from the south in late spring or early summer and remain until autumn.

The period chosen for the model was 1985 to 1987. This was a time of relatively constant biomass for the major commercial species, in particular those groundfish whose biomasses were low prior to extension of jurisdiction in 1977, increased in the late 1970s and early 1980s, and decreased again during the mid to late 1980s and early 1990s. It is also the period for which there are most data for the diets of demersal fish, mainly because of seasonal sampling in Division 3L in the period 1984-1986. An additional consideration was partial avoidance of the very cold period centred on 1983-1984.

In the present paper, the mass balance model of the Newfoundland-Labrador Shelf that was initiated at the 1993 workshop is greatly revised, updated and presented at an advanced state. The structure of the model has been altered and parameter estimates either updated or made anew. The time period and area of the model remain the same, except that the seaward boundary has been extended from the 500 m isobath to the 1000 m isobath. Many colleagues have contributed data, analyses and advice. These people are listed in Appendix 1, and are identified at the start of those sections to which they contributed.

Description of approach

The necessary condition in the ECOPATH approach for mass balance is:

$$P_i - M0_i - M2_i - C_i = 0 \tag{1}$$

where

P_i = the annual biomass produced by species i
$M0_i$ = annual biomass loss of species i not accounted for by any predator group included in the model nor by catch or export, that is, other mortality
$M2_i$ = annual biomass of species i consumed by all predator groups included in the model, that is, predation mortality
C_i = annual catch of species i.

$M2_i$ is obtained by summing the annual consumption of species group i by all j predator groups included in the model, so that

$$M2_i = \sum p_{ij} Q_j \tag{2}$$

where

p_{ij} = proportion by mass of predator j's diet that is comprised of prey i
Q_j = the annual consumption of biomass by predator j.

$M0$, other mortality, is expressed in Ecopath as $1\text{-}EE_i$ where EE_i is the "ecotrophic efficiency". In these terms $1\text{-}EE_i$ is the proportion of P_i that is not consumed by predators included in the model, nor caught by the fishery, so that,

$$EE_i = (M2_i + C_i) / P_i \tag{3}$$

The ecosystem is modelled using a set of simultaneous linear equations derived from the above relationships. Equation (1) is scaled by biomass. Thus production and consumption are expressed as biomass ratios (P/B, Q/B). M0 and M2 are instantaneous mortality rates. Each group in the model is represented by one balanced equation and requires six input parameters. Diet composition and catch (export) must be entered and three of the other four parameters (B, P/B, Q/B, and EE) must be entered. The linear equations are solved and any missing parameters are estimated. (EE is estimated if all other parameters have been entered.) Polovina's (1984) original Ecopath may be used to estimate the biomass. However, it is more robust to enter B, P/B and Q/B where possible and allow the model to estimate EE. This provides an immediate check for mass-balance because EE cannot be greater than 1. Sometimes it is necessary to enter EE in which case a default value of 0.95 is used (Christensen and Pauly 1992).

In most cases, when all the information to run a model is assembled, the model will not balance. In such cases, the values of one or more of the terms can be altered iteratively until a balance is obtained. This may be done using the Ecoranger routine of Ecopath 3.0. This procedure enables the user to enter a range of values for each parameter, and assign a probability to them. The model is then fitted on a user-based goodness of fit test[1]. Thus, parameters with robust data can be used to constrain the model, while for less certain parameters a range of values may be entered.

There is more than one way to construct an Ecopath model and there is more than one solution to any model. However, if there are areas of the model which are well known and on which the modeller can place some certainty, then the number of plausible solutions is reduced. For the less certain parameters, sensitivity analysis can be used to examine their effects on the model.

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[1] For further information, see http:\\www.ecopath.org

Parameter Estimation

A total of 31 groups were defined in the model. Where possible, scientists with specific knowledge of a group were consulted in the estimation of the parameters. In addition, these specialists co-wrote the appropriate parameter estimation sections below. A full list of specialists and their contact information is given in Appendix 1.

Biomass

Biomass was estimated from sequential population analysis, trawl survey data or hydroacoustics data for most groups in the model. There are two types of trawl survey data, Engels trawl data, which dates up to spring 1995, and Campelen trawl data, which dates from autumn 1995 onwards. The Campelen gear is more efficient at catching small fish and as such, is considered to give a better estimate of true biomass than the Engels data. Engels data have been converted to Campelen units for some species. The Campelen converted data have been used here when available. However, even with the Campelen converted data, biomass estimates are likely to apply only to a certain proportion of biomass, that which is recruited to the sample gear. To allow for the biomass of pre-recruits, two methods were used. The preferred method was to back-calculate numbers at age in the pre-recruits from a known number of first year recruits, assuming a natural mortality rate, and then to multiply by mean weight-at-age to get mean biomass-at-age. The alternative method was to raise the biomass estimate by a "bump-up factor". For those groups that are only present in the model area for part of the year, their biomass was pro-rated by the proportion of the year that they were present in the model area.

Production

Christensen and Pauly (1992) define production as the total amount of tissue elaborated in the population or community under study during a given time period. Measurement of this production over the time period requires knowledge of the biomass of the population at the beginning and the end of the period and the mass of living components that have been lost by death or emigration during the period. In the Labrador-Newfoundland model it is assumed that there is no year to year change in biomass over the 1985-87 time period and that emigration is zero. Thus production in this model is simply the biomass that is lost to natural mortality and fishing mortality. In many Ecopath models, production, or more specifically, the production to biomass ratio (P/B), is estimated by assuming that P/B is equal to total mortality (Allen 1971). An alternative method is to estimate production from virtual population analysis, or MSVPA, as was done for some species in the North Sea (Christensen 1995). Both methods carry assumptions, as discussed below, and neither explicitly considers gonadic production.

Ricker (1946) provided a method for calculating production from instantaneous body growth rate (in terms of weight) and instantaneous total mortality rate. This approach assumes that the two rates remain constant over the lifespan of the animal (Allen 1971). Allen (1971) examined several models for which mortality and growth vary over the lifespan. While for some models the ratio of P/B is a complex function of growth rate and mortality rate, Allen

(1971) found that P/B = Z for models in which total mortality is a constant exponential rate (i.e. $N_t = N_0 e^{-Zt}$), irrespective of the form of the body growth rate function. Allen (1971) also provides relationships between P/B and mean age or mean life span for different mortality and growth functions. Mertz and Myers (1998) have also examined the relationship between production, biomass and mortality and shown that P/B = Z, the biomass averaged total mortality.

Production calculated from virtual population analysis is simply calculated as the difference between the biomass of the population at the beginning and the end of the year. This difference is assumed to be the production, that is, the biomass lost to fishing mortality and natural mortality (predation, disease and other natural causes of death). However, using this approach entails assuming a value for natural mortality. This parameter is not well known, and is estimated by Ecopath as predation mortality, plus other mortality. Assuming a value of M is equivalent to setting a prior natural mortality, assuming a component of production and forcing the model to accommodate this M.

An additional problem with both approaches is that neither deals specifically with the annual elaboration of tissue into gonads. This may be a considerable proportion of annual production for mature fish. Some of it is consumed directly through predation on fish with developed gonads prior to spawning. Some of the gonadic production is consumed or dies immediately after spawning, before fertilisation, while some ends up as icthyoplankton with production, mortality and growth rates similar to that of other components of the zooplankton. Icthyoplankton are subject to a similar suite of predators as other members of the zooplankton that are in the same size range. Some of the icthyoplankton may be lost through transport in ocean currents out of the system.

In order to investigate methods of estimating production in this model, and to determine whether gonadic production is important, production was estimated for cod and American plaice using 3 approaches: (i) Z was estimated from catch curve analysis of RV survey data, (ii) somatic production was estimated using VPA-based methods and (iii) somatic plus gonadic production was estimated using VPA-based methods.

For the third method, gonadic production was calculated for all mature fish that survived until the end of the year and for 50% of the mature fish that died. This assumes that they all die half way through the year. Gonadic production was estimated, for each age group, as the weight of the ripe gonad multiplied by the proportion mature at age for each sex, times the number of fish. A 1:1 sex ratio was assumed. Gonad weights were estimated for cod and American plaice. The results are shown in Table 1.

Table 1 Comparison of P/B estimates using different methods.

Method of P/B Estimation	*Atlantic cod (Ages 3+)*	*American plaice (Ages 8+)*
Catch Curve	0.65	0.52
VPA-based	0.38	0.47
VPA-based + Gonadic Production	0.46	0.51

The inclusion of gonadic production increases the P/B ratio by 17% for Atlantic cod and 7% for American plaice. All of the American plaice P/B estimates are similar, regardless of which method is used. However, the catch curve estimate of P/B (=Z) for Atlantic cod is higher than the two VPA-based methods. Thus for Atlantic cod, including gonadic production does not give the highest estimate of production. In all likelihood, the lower P/B estimates from the VPA-based methods reflect the inaccuracy of assuming that natural mortality = 0.2 yr^{-1}. On the basis of these results, and to avoid making assumptions about natural mortality, where possible catch curve analysis was used to estimate P/B, assuming that P/B = Z (Allen 1971). It was not possible to estimate Z this way for all groups. For such groups, other estimates of Z or P/B values from the literature were used, or, for commercial species, production was estimated as the sum of the biomass times an assumed natural mortality plus the catch.

The question about the fate of gonadic productivity remains. Here it is assumed that the uncertainty around the catch curve (or other) estimate of Z will allow for gonadic productivity. This is reasonable for species such as American plaice where gonadic production only increased production by 7%. It may also hold for cod-like species. Icthyoplankton, the surviving gonadic products, are included in the large zooplankton group.

Consumption

Consumption was estimated from field studies where possible, either from the region, or for species from similar areas reported in the literature. In addition, models were used to estimate consumption by marine mammals and seabirds. Where it was not possible to do either, Q/B values were taken from the literature and/or estimated, assuming a P to Q ratio of 0.15 (after Christensen, 1995).

Diet

The diet of many species varies temporally and spatially. For fish, there may also be considerable variation with size. Thus, to obtain an adequate representation of the annual diet, one would have to obtain stomach content data for the full size range of each species throughout its distribution in the study area with a temporal frequency sufficient to capture any seasonal variability. In addition, there should be appropriate adjustment for variability in population numbers (or biomass) at length and for variability in digestive rate associated with prey type and temperature. For some species (e.g. harp seals, Atlantic cod, Greenland halibut and American plaice) the participants had access to stomach content data collected from the study area during 1985-1987. For none of these species have the stomach collections covered the whole geographic area throughout the year. For the fish species, the average diets are calculated from the available stomach content data without adjustments for population size structure and variability in digestion rates. For many species or groups, there were no stomach content data available to the authors. In some of these cases diet information was available from literature reports from the study area, although often from time periods other than 1985-1987. In the worst cases (eg. small demersal-feeding fish), it was necessary to make educated guesses based solely on general diet descriptions from outside the study area.

Species groups

Species groups were defined on the basis of their commercial significance and importance as predators or prey.

Size Groupings

Atlantic cod, Greenland halibut and American plaice were each separated into two groups based on diet, age/size of first capture and age/size of maturity. Smaller animals prey mainly on invertebrates and larger animals prey mainly on fish. These changes tend to occur gradually with increasing length, but for this model it was assumed that the change occurs at 35 cm for Atlantic cod (Lilly and Fleming 1981; Lilly 1991) and American plaice (Pitt 1973) and 40 cm for Greenland halibut (Bowering and Lilly 1992).

Input data by Ecopath group

The input parameters (Biomass, P/B and Q/B) are given in Table 2a. Also given are the EEs and GEs. Some of these are input parameters, whilst others are estimated by the model (in italics). The diet matrix is given in Table 2b.

Table 2a. Initial input parameters for the Ecopath model. The values in italics were estimated by the model. The members of each group are described in the relevant section of the text. L.Dem.Feeders are large demersal feeders. S.Dem.Feeders are small demersal feeders. L.Pel.Feeders are large pelagic feeders. Pisc. SPF and Plankt. SPF are piscivorous and planktivorous small pelagic feeders. O.Benthic Inver are other benthic invertebrates.

Group Name	*Biomass* $t \cdot km^{-2}$	*P/B* yr^{-1}	*Q/B* yr^{-1}	*EE*	*GE*
1. Whales	0.251	0.100	11.794	*0.000*	*0.008*
2. Harp Seals	0.184	0.102	17.412	*0.053*	*0.006*
3. Hooded Seals	0.034	0.109	13.100	*0.000*	*0.008*
4. Seabirds	0.012	0.250	54.750	*0.333*	*0.005*
5. Cod > 35cm	2.044	0.651	3.240	*0.516*	*0.201*
6. Cod <= 35 cm	0.094	0.600	6.090	*7.744*	*0.099*
7. G.halibut > 40cm	0.348	0.508	1.478	*0.361*	*0.344*
8. G.halibut <= 40cm	0.165	0.247	3.401	*9.641*	*0.073*
9. Aplaice > 35cm	0.972	0.538	1.262	*0.191*	*0.426*
10. Aplaice <= 35cm	0.784	0.625	3.736	*0.530*	*0.167*
11. Flounders	0.868	0.394	3.600	*1.150*	*0.109*
12. Skates	0.517	0.286	2.878	*0.264*	*0.099*
13. Redfish	0.975	0.330	2.000	*1.789*	*0.165*
14. L.Dem.Feeders	0.845	0.262	*1.747*	*0.676*	0.150
15. S.Dem.Feeders	0.227	0.300	*2.000*	*15.139*	0.150
16. Capelin	13.289	1.145	6.400	*0.740*	*0.179*
17. Sand lance	2.103	1.150	*7.667*	*1.196*	0.150
18. Arctic cod	2.729	0.395	*2.633*	*0.913*	0.150
19. L.Pel.Feeders	*0.029*	0.400	3.333	0.950	*0.120*
20. Pisc. SPF	0.453	0.265	*1.767*	*6.805*	0.150
21. Plankt. SPF	0.950	0.240	*1.600*	*4.378*	0.150
22. Shrimp	0.202	1.450	*9.667*	*2.756*	0.150
23. Large Crustacea	0.185	0.282	5.850	*20.874*	*0.048*
24. Echinoderms	112.300	0.600	*6.667*	*0.022*	0.090
25. Molluscs	42.100	0.570	*6.333*	*0.035*	0.090
26. Polychaetes	10.500	2.000	*22.222*	*0.116*	0.090
27. O.Benthic Inver	7.800	2.500	*12.500*	*0.115*	0.200
28. Lge.Zooplankton	18.343	3.433	19.500	*1.095*	*0.176*
29. Sm.Zooplankton	21.700	6.200	20.667	*1.729*	*0.300*
30. Phytoplankton	26.860	93.100	0.000	*0.232*	-
31. Detritus	389.000	-	-	*0.576*	-

Table 2b. Diet matrix for the initial Ecopath model.

Prey \ Predator	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
1. Whales	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2. Harp Seals	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3. Hooded Seals	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4. Seabirds	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5. Cod > 35cm	0.000	0.013	0.093	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6. Cod <= 35 cm	0.012	0.034	0.000	0.005	0.018	0.007	0.076	0.009	0.000	0.004	0.000	0.050	0.002	0.011	0.000
7. G.halibut > 40cm	0.000	0.004	0.036	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8. G.halibut <= 40cm	0.000	0.045	0.290	0.000	0.006	0.002	0.127	0.005	0.001	0.002	0.000	0.001	0.000	0.000	0.000
9. Aplaice >35 cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10. Aplaice <= 35cm	0.000	0.010	0.000	0.000	0.017	0.000	0.001	0.000	0.001	0.021	0.000	0.001	0.000	0.017	0.000
11. Flounders	0.000	0.050	0.216	0.000	0.001	0.000	0.002	0.000	0.000	0.008	0.000	0.007	0.000	0.011	0.000
12. Skates	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
13. Redfish	0.000	0.005	0.049	0.000	0.009	0.000	0.256	0.000	0.000	0.001	0.000	0.086	0.007	0.016	0.000
14. L.Dem.Feeders	0.033	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15. S.Dem.Feeders	0.033	0.047	0.120	0.016	0.040	0.024	0.086	0.008	0.009	0.023	0.007	0.111	0.001	0.042	0.010
16. Capelin	0.489	0.319	0.008	0.700	0.602	0.430	0.383	0.834	0.297	0.333	0.025	0.080	0.007	0.039	0.020
17. Sand lance	0.052	0.095	0.000	0.050	0.105	0.031	0.000	0.000	0.169	0.091	0.025	0.145	0.004	0.027	0.010
18. Arctic cod	0.000	0.219	0.014	0.060	0.022	0.032	0.027	0.050	0.001	0.004	0.000	0.001	0.000	0.000	0.005
19. L.Pel.Feeders	0.000	0.001	0.000	0.001	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20. Pisc. SPF	0.163	0.051	0.028	0.016	0.001	0.005	0.006	0.010	0.000	0.000	0.000	0.058	0.000	0.001	0.002
21. Plankt. SPF	0.030	0.038	0.147	0.029	0.004	0.014	0.017	0.030	0.000	0.000	0.000	0.007	0.245	0.034	0.003
22. Shrimp	0.000	0.036	0.000	0.006	0.037	0.079	0.013	0.022	0.003	0.013	0.007	0.022	0.035	0.090	0.020
23. Large Crustacea	0.000	0.000	0.000	0.000	0.048	0.022	0.000	0.000	0.045	0.021	0.000	0.311	0.000	0.026	0.010
24. Echinoderms	0.000	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.298	0.112	0.053	0.007	0.000	0.199	0.100
25. Molluscs	0.000	0.000	0.000	0.001	0.023	0.006	0.000	0.000	0.081	0.031	0.035	0.015	0.000	0.067	0.100
26. Polychaetes	0.000	0.000	0.000	0.000	0.006	0.017	0.000	0.000	0.017	0.111	0.470	0.080	0.000	0.080	0.200
27. O.Benthic Inver	0.000	0.003	0.000	0.000	0.010	0.139	0.001	0.003	0.058	0.134	0.351	0.013	0.000	0.141	0.420
28. L.Zooplankton	0.104	0.029	0.000	0.111	0.047	0.193	0.003	0.029	0.021	0.092	0.027	0.004	0.538	0.185	0.050
29. S.Zooplankton	0.083	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.161	0.014	0.050
30. Phytoplankton	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
31. Detritus	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 2b. Diet matrix for the initial Ecopath model (cont.).

Prey \ Predator	*16*	*17*	*18*	*19*	*20*	*21*	*22*	*23*	*24*	*25*	*26*	*27*	*28*	*29*	*30*
1. Whales	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2. Harp Seals	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3. Hooded Seals	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4. Seabirds	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5. Cod > 35cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6. Cod <= 35 cm	0.000	0.000	0.000	0.002	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7. G.halibut > 40cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8. G.halibut <=40 cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9. Aplaice >35 cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10. Aplaice <=35 cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11. Flounders	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12. Skates	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13. Redfish	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14. L.Dem.Feeders	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15. S.Dem.Feeders	0.000	0.000	0.000	0.035	0.000	0.000	0.000	0.050	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16. Capelin	0.010	0.000	0.038	0.075	0.698	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17. Sand lance	0.010	0.000	0.000	0.086	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18. Arctic cod	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19. L.Pel.Feeders	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20. Pisc. SPF	0.000	0.000	0.000	0.273	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
21. Plankt. SPF	0.000	0.000	0.000	0.187	0.083	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22. Shrimp	0.000	0.000	0.000	0.012	0.008	0.005	0.000	0.049	0.000	0.000	0.000	0.000	0.000	0.000	0.000
23. Large Crustacea	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.111	0.000	0.000	0.000	0.000	0.000	0.000	0.000
24. Echinoderms	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.200	0.000	0.000	0.000	0.000	0.000	0.000	0.000
25. Molluscs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.198	0.000	0.000	0.000	0.000	0.000	0.000	0.000
26. Polychaetes	0.000	0.000	0.000	0.003	0.000	0.000	0.015	0.196	0.000	0.000	0.000	0.000	0.000	0.000	0.000
27. O.Benthic Inver	0.000	0.000	0.000	0.019	0.000	0.050	0.015	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
28. L.Zooplankton	0.434	0.350	0.640	0.295	0.168	0.526	0.120	0.049	0.000	0.000	0.000	0.000	0.050	0.000	0.000
29. S.Zooplankton	0.546	0.650	0.320	0.012	0.013	0.419	0.240	0.049	0.000	0.000	0.000	0.000	0.460	0.000	0.000
30. Phytoplankton	0.000	0.000	0.000	0.000	0.000	0.000	0.085	0.000	0.000	0.000	0.000	0.000	0.370	1.000	0.000
31. Detritus	0.000	0.000	0.000	0.000	0.000	0.000	0.525	0.097	1.000	1.000	1.000	1.000	0.100	0.000	0.000

1. Whales and porpoises (Stenson, Lawson and Bundy)

Background

The main piscivorous whales in the study area are humpback (*Megaptera novaeangliae*), fin (*Balaenoptera physalus*), minke (*Balaenoptera acutorostrata*), sei (*Balaenoptera borealis*), sperm (*Physeter catodon*) and pilot (*Globicephala melaena*). The main porpoise species is the harbour porpoise (*Phocoena phocoena*). The only baleen whale in the area that does not feed on fish is the planktivorous blue whale (*Balaenoptera musculus*) (Gaskin 1982).

Catch

There are no catches of these species recorded for the study area for the 1985-87 period. Canada ceased commercial whaling in 1972.

Biomass

Population sizes have been estimated at: humpback - 3,300, backcalculated from a total of 10,000-11,000 in the NW Atlantic in 1992/3 and assuming 45-50% in Newfoundland waters and a 6.7 % growth rate (Barlow and Clapman 1997; P. Hammond, Sea Mammal Research Unit, UK. *pers. comm.*); fin - 1,000 (Hay 1982; Mitchell 1974); minke - 5,000 (based on a range of 74,700 to 145,000 in the northern Atlantic, Anon 1991); sei - 1,000 (Mitchell and Chapman 1977); sperm - 1,000 (Braham 1984); pilot - 9,000 (Nelson and Lien 1996, projected from 4,000 in 1972 using a 6% net recruitment rate); harbour porpoise - 20,000 (Gaskin 1992, backcalculated from 1992 using 3% growth rate and assuming 50% of the Newfoundland population was in 2J3KLNO, B. Sjare, *pers. comm.*); blue whale - 200 (Mitchell 1974; the 1974 value was taken as representative of the average population in the 1985-1987 period).

A range of mean body weights appear in the literature, see Table 3. In the absence of definitive mean weights, an average of these values was taken. The Martin (1990) estimate for the sperm whale was used however, because only males migrate as far north as Newfoundland and these are heavier than the females (P. Hammond, *pers. comm.*).

Table 3 Mean body weights (t) of whales from various literature sources.

	Miscellaneous	*Kenney et al (1997)*	*Martin (1990)*	*Average*	*Revised*
Humpback	32[1]	25	36	31	31
Fin	40.5[2]	30	45	38.5	38.5
Minke	6.3[2]	4.5	6	5.6	5.6
Sei	15[2]	13	15	14.3	14.3
Sperm	28[2]	20	45	31	45
Pilot	1.8[2]	0.85	1.5	1.4	1.4
Harbour	0.065[2]	0.045	0.05	0.05	0.05
Blue	70[3]	70	90	76.7	76.7

[1] Hay (1985), [2] Lien (1985), [3] Lien (1985), Ichihara (1966)

This gives biomass values (t) of: humpback - 102,300, fin - 38,500, minke - 28,000, sei - 14,333, sperm - 45,000, pilot - 12,450, harbour porpoise - 1,067, and blue whale - 15,333 and a total biomass for the area of 251,983 t. Assuming a residency time of 125 days for the blue whale and 180 days for all other whales within the study area, the average annual biomass was 124,421 t, 0.251 t·km^{-2}.

Production:Biomass

Annual production within the study area was calculated by assuming a production to biomass ratio of 10%, giving 17,993 t.

Consumption:Biomass

Annual consumption by species was calculated assuming a residency time of 180 days (125 for blue whale) and percentages of body weight or tonnes consumed per day per individual of: humpback, fin, minke, and sperm - 3% (Lockyer 1981), sei - 0.9 t (Lien 1985), pilot - 3% (assuming that its rate is the same as other cetaceans whose mean weight is greater than 0.6 t, Gaskin (1982:85)), harbour porpoise - 0.0045 t (Lien 1985) and blue whale, 2.7 t in the Northwest Atlantic (Lien 1985). This gives an annual consumption by species group of: humpback - 552,420 t; fin - 207,900 t; minke - 151,200 t; sei - 162,000 t; sperm - 243,000 t; pilot - 67,230 t; harbour porpoise - 16,200 t and blue whale 67,500 t. This gives a mean annual consumption of 1,467,450 t and an annual Q/B ratio of 11.79 yr^{-1}.

Diet

There are few quantitative descriptions of diet. Where the literature refers to a prey using the terms "preponderant" or "predominant", or similar terms, it was assumed that this species represents at least 75% of consumption by weight (Table 4). If other prey species are reported, the remaining consumption was divided equally among them. Based on the literature, the following diets were used in the analysis: humpback - capelin, euphausiids, squid and sand lance (Mitchell 1973); fin - capelin, sand lance, herring and euphausiids (Mitchell 1975); minke - capelin, pre-recruited cod, herring, squid and euphausiids (Horwood 1990, after Mitchell 1974); sei - copepods, euphausiids, capelin and sand lance (Mitchell 1975); sperm - squid, large demersal feeders, small demersal feeders (Gaskin 1982); pilot - squid, pre-recruited cod and capelin (Lien 1985); harbour porpoise - capelin, pre-recruited cod and mackerel (Lien 1985); blue whale - large zooplankton species *Thysanoessa inermis, Temora longicornis* and *Meganyctiphanes norvegica* (Gaskin 1982; Mitchell 1975).

In order to calculate the overall proportion of each prey type by weight in the whale diet, total consumption by prey type was first calculated, and then the overall proportions, as shown in Table 4. These are shown by the groupings used in the Ecopath model.

Table 4. Diet composition of whales in the study area.

Ecopath Group	*Humpback*	*Fin*	*Minke*	*Sei*	*Sperm*	*Pilot*	*Harbour Seal*	*Blue*	*Mean Diet*
6 Cod <= 35 cm	0	0	0.050	0	0	0.125	0.125	0	0.012
14 Demersal feeders (misc. large)	0	0	0	0	0.200	0	0	0	0.033
15 Demersal feeders (misc. small)	0	0	0	0	0.200	0	0	0	0.033
16 Capelin	0.750	0.750	0.750	0.083	0	0.125	0.750	0	0.489
17 Sand lance	0.083	0.083	0	0.083	0	0	0	0	0.052
20 Pisc. Pelagic feeders (misc. small)	0.083	0	0.050	0	0.550	0.750	0.125	0	0.163
21 Plankt. Pelagic feeders (misc. small)	0	0.083	0.1	0	0.050	0	0	0	0.030
28 Zooplankton (large)	0.083	0.083	0.050	0.083	0	0	0	1.000	0.104
29 Zooplankton (small)	0	0	0	0.750	0	0	0	0	0.083
TOTAL	1	1	1	1	1	1	1	1	1

2. Harp seals (Stenson and Bundy)

Background

The northwest Atlantic population of harp seals (*Phoca groenlandica*) comprises two herds, one that breeds in the Gulf of St. Lawrence (Gulf herd) and on that breeds on the pack ice off southern Labrador (Front herd). Generally, harp seals summer in the Canadian Arctic or Greenland, and winter in Atlantic Canadian waters. Both herds are assumed to spend a portion of the year in the model area (2J3KLNO) although the residency period for Gulf seals is brief.

Catch

Annual removals (total numbers) from the Front herd were taken as reported in the NAFO Statistical Bulletins (NAFO 1987, 1989, 1990). The number of young of the year removed was obtained directly from the catch statistics. The age structure of older (1 year of age and older) seals in the harvest was estimated using aged sub-samples of the catch for the period 1985-1987 (Sjare *et al.* 1996). Numbers at age were multiplied by the mean weight at age, (Chabot *et al.* 1996, estimated from a Gompertz growth curve). The total mean annual catch for 1985-1987 was estimated as 441.6 t, or 0.0009 $t{\cdot}km^{-2}$ for the total area of 2J3KLNO.

Biomass

Biomass was estimated from the abundance, multiplied by the mean weight at age as described above. The number of seals in each age class was obtained from the population model of Shelton *et al.* (1996a). Formulation 2 was used, where pup mortality was assumed to be 3 times the mortality rate of the rest of the population. The number of seals in each age group present in the 2J3KLNO area was estimated from the seasonal distribution of harp seals, given in Hammill and Stenson (1998). The mean annual biomass for 1985-1987 was calculated as 91,198.4 t, or 0.184 $t{\cdot}km^{-2}$ for the total area.

Production:Biomass

It was assumed that the production:biomass ratio is equivalent to the total mortality rate, Z (Allen 1971). Total mortality was estimated from a weighted mean of the survival rates in Shelton *et al.* (1996a), giving a P/B of 0.102 yr^{-1}, and a total annual production of 9340.2 t.

Consumption:Biomass

Total annual consumption of each prey species in the study area was estimated from the consumption model of Stenson *et al.* (1997) and modified by Hammill and Stenson (1998). The average annual consumption was 1,588,111 t, producing a consumption:biomass ratio of 17.4 yr^{-1}.

Diet

The harp seal diet is an average diet derived from samples obtained from 1982-1995. Diets were applied seasonally and separate diets are used for seals in nearshore (Lawson and Stenson, 1995; Lawson *et al.* 1995) and offshore areas (Lawson and Stenson 1997). The diets assumed are summarized in Hammill and Stenson (1998). The relative proportions of the split pools prey groups (Atlantic cod, Greenland halibut and American plaice) are estimated from selectivity data in Lawson and Stenson (1997) and Lawson *et al.* (1995). The composition of the "other fish" and "other invertebrate" groups in Hammill and Stenson (1998) were determined from the original papers. The diet composition is given in Table 2b.

3. Hooded seals (Stenson, Hammill and Bundy)

Background

Hooded seals (*Cystophora cristata*) are larger than harp seals but much less abundant within the study area. Whelping takes place on pack ice off northeast Newfoundland and in Davis Strait and the Gulf of St. Lawrence. Little is known about stock relationships between the 3 groups. All pups remain in Arctic waters, having migrated there after whelping, and most remain as juveniles (1-3 years old). Hooded seals migrate north out of the study area in April and return in the fall.

Catch

The annual number of hooded seals harvested in 1985-87 was obtained from Anon (1998). An average of 891 seals were caught each year but numbers varied greatly among years. In 1986, for example, there was a very low catch of hooded seals. The number of pups harvested was 21 while in 1987 it was 1321. The number of 1+ seals in the catch was estimated by dividing the catch by the proportion at age in the population obtained from a population model (Hammill and Stenson 1998). Catch weight was then estimated using the Gompertz growth equation for hooded seals described in Hammill and Stenson (1998). The mean annual weight of hooded seals caught was 19.5 t of pups and 69.1 t of 1+ seals, making a total catch of 88.7 t of hooded seals, or 0.000179 $t \cdot km^{-2}$.

Biomass

The number of seals in each age class was estimated using the population model presented in Hammill and Stenson (1998), back calculated to the period 1985-1987 using an annual growth rate of 4.8%, and adjusted for seasonal distribution (Hammill and Stenson 1998). Numbers were then converted to biomass-at-age using the Gompertz growth equation, as above. Hooded seal pups are only resident in the area for about a month. To allow for this, the population number of hooded seal pups was divided by twelve to obtain the mean annual biomass in the area. Pups were assumed to undergo their post-weaning fast when they are in 2J3KLNO and therefore are not included in the consumption estimate below. The total mean annual biomass of hooded seals is 16, 810 t, or 0.034 $t{\cdot}km^{-2}$.

Production:Biomass

It was assumed that the production:biomass ratio is equivalent to the total mortality rate, Z (Allen 1971). Total mortality was estimated from the survival rates in Hammill and Stenson (1998), weighted by the biomass of juveniles and adults. This gives a mean P/B of 0.109 yr^{-1}, and a total annual production of 1829 t.

Consumption:Biomass

Total annual consumption was estimated from the consumption model of Hammill and Stenson (1998) and back-calculated from 1990 to the1985-1987 period (Stenson, unpubl.). The average annual consumption was 220,209 t, producing a consumption:biomass ratio of 13.1 yr^{-1}.

Diet

The diet information was taken from Hammill and Stenson (1998), which is based on Ross (1993) and Lawson and Stenson (unpublished data). Ross (1993) reconstructed the diet of hooded seals using 132 prey-containing stomachs (collected mainly in springs of 1982-1991). The Atlantic cod and Greenland halibut components of the diet were split into the two size groups, based on selectivity data in Ross (1993). The main components of the diet are young Greenland halibut, flounders and small pelagic feeders, see Table 2b.

4. Seabirds (Montevecchi)

Background

There are large seasonal fluxes of seabird species and populations in the study area throughout the year. The major species that breed in the region are Leach's storm-petrel (*Oceanodroma leucorhoa*), northern gannet (*Sula bassana*), ring-billed gull (*Larus delawarensis*), herring gull (*L. argentatus*), great black-backed gull (*L. marinus*), black-legged kittiwake (*Rissa tridactyla*), common tern (*Sterna hirundo*), arctic tern (*S. paradisaea*), common murre (*Uria aalge*), thick-billed murre (*U. lomvia*), razorbill (*Alca torda*), and Atlantic puffin (*Fratercula arctica*) (Montevecchi and Tuck 1987, Cairns *et al.* 1989). Other species that breed in the study area in small numbers are northern fulmar (*Fulmarus glacialis*), Manx shearwater (*Puffinus puffinus*), great cormorant (*Phalacrocorax carbo*), double-crested cormorant (*P. auritus*), common black-headed gull (*Larus ridibundus*), Caspian tern (*Sterna caspia*), and black guillemot (*Cepphus grylle*).

The major species that move into the region in large numbers for substantial periods, primarily during summer, but do not breed in the study area, are the transequatorial migrants - greater shearwater (*Puffinus gravis*), and sooty shearwater (*P. griseus*). Species that breed in the Arctic and Northeast Atlantic and move into the region in large numbers during winter are northern fulmar, Iceland gull (*Larus glaucoides*), glaucous gull (*L. hyperboreus*), black-legged kittiwake, dovekie (*Alle alle*) and thick-billed murre. In the present treatment, the seaducks and common eider (*Somateria dresseri*) are included with species that breed in the region. Common eider, oldsquaw (*Clangula hyemalis*) and scoters (*Melanitta* spp.) are included with species that breed primarily outside the study area.

Catch/Anthropogenic Mortality

There are three primary additive sources of anthropogenic mortality on seabirds in the region: 1) by-catch in fishing gear, 2) hunting, and 3) oil pollution (Montevecchi and Tuck 1987). Considerable numbers of seabirds, (mostly alcids, i.e. murres and puffins, but also others, e.g. gannets) are caught as by-catch in fishing gear. The significance of this mortality may be indicated in part by population increases of murres in the Witless Bay Seabird Ecological Reserve in eastern Newfoundland that appear to have occurred since 1992, when fixed fishing gear was removed from coastal waters following the Eastern Canadian Ground-fishery Moratorium. It has been estimated that each winter as many as 500,000 thick-billed (and common) murres are killed by hunters in Newfoundland and Labrador (Montevecchi and Tuck 1987, Elliot *et al.* 1990). This hunting pressure has likely decreased in the 1990s with the introduction of seasonal and bag limits by the Canadian Wildlife Service. Additionally, tens of thousands of seabirds and seaducks are estimated to be killed each year by illegal discharges of oil by ships, and this mortality appears to be greatest in winter. On the basis of this information, a "guesstimate" of 500,000 seabirds x mean mass of 0.93 kg = 465 t, 0.001 $t\cdot km^{-2}$, of seabirds being removed from the study area annually through by-catch, hunting and oiling.

Biomass

Data on body masses and population estimates were derived from Montevecchi *et al.* (1984, 1987, 1988a), Nettleship and Chapdelaine (1988), Diamond *et al.* (1986, 1993), Cairns *et al.* (1989), Sklepkovych and Montevecchi (1989), Storey and Lien (1985), Stenhouse and Montevecchi (1999) and Montevecchi (unpublished data). For species that breed within NAFO Areas 2J3KLNO, population estimates = estimated breeding pairs x 2 + [0.30 x breeding pairs x 2] non-breeders + [0.80 x breeding pairs (fulmar, Manx shearwater, storm-petrel, gannet, cormorants, murres, puffin)] or [1.0 x breeding pairs (gulls, terns, guillemot) or 2.0 x breeding pairs (eider)].

Population estimates and durations of seabird species are summarised in Table 5. The average body mass and total biomass are given for each species. The overall biomass estimate for the study area is 6101 t, or 0.012 $t\cdot km^{2}$.

Table 5. Approximate occupation dates, estimated population numbers, average body masses and average annual biomass for the main species of seabird that occur within the study area (NAFO Divisions 2J3KLNO) and A) breed there or B) breed primarily or completely outside of the study area. Note that northern fulmar, common eider, thick-billed murre and dovekie occur in both partitions of the table.

A) Seabird species that breed within NAFO Divisions 2J3KLNO.

Species	*Occupation dates*	*Population (number)*	*Individual mass (kg)*	*Average biomass over year (t)*
Northern fulmar	Jan-Dec	181	0.80	0.14
Manx shearwater	Mar-Nov	340	0.48	0.12
Leach's storm-petrel	Apr-Oct	15,340,636	0.05	447.44
Northern gannet	Apr-Oct	48,806	3.20	91.10
Great cormorant	Mar-Nov	601	2.25	1.01
Double-crested cormorant	Mar-Oct	1,048	2.33	1.63
Common eider	Jan-Dec	2,344	2.23	5.23
Black-headed gull	Jan-Dec	25	0.28	0.01
Ring-billed gull	Apr-Oct	23,062	0.50	6.73
Herring gull	Jan-Dec	151,787	1.12	170.00
Great black-backed gull	Jan-Dec	12,460	1.68	20.93
Black-legged kittiwake	Jan-Dec	293,822	0.44	129.28
Caspian tern	May-Oct	108	0.61	0.03
Common tern	May-Oct	11,128	0.12	0.67
Arctic tern	May-Oct	16,358	0.11	0.90
Common murre	Jan-Dec	1,912,857	0.99	1893.73
Thick-billed murre	Jan-Dec	40,800	0.93	37.94
Razorbill	Jan-Dec	37,305	0.69	25.74
Black guillemot	Jan-Dec	54,000	0.40	21.60
Atlantic puffin	Jan-Dec	1,032,855	0.46	475.11
TOTAL	Jan-Dec	18,970,651		3329.35

B) Seabird species that occur within and breed mostly or completely outside of NAFO Divisions 2J3KLNO.

Species	*Occupation dates*	*Population (number)*	*Individual mass (kg)*	*Average biomass over year(t)*
Wilson's storm-petrel	May-Oct	50,000	0.04	1.00
Northern fulmar	Jan-Dec	300,000	0.80	240.00
Greater shearwater	May-Oct	1,500,000	0.89	667.50
Sooty shearwater	May-Oct	300,000	0.79	118.50
Oldsquaw	Nov-Apr	15,000	0.76	5.70
Scoter spp.	Oct-Apr	40,000	1.11	25.90
Common eider	Nov-Mar	50,000	2.23	46.46
Iceland gull	Oct-Apr	100,000	0.86	50.17
Glaucous gull	Oct-Apr	50,000	1.70	49.58
Black-legged kittiwake	Oct-Apr	500,000	0.44	128.33
Thick-billed murre	Oct-Apr	1,500,000	0.93	813.75
Dovekie	Nov-Mar	10,000,000	0.15	625.00
TOTAL	Jan-Dec	14,475,000		2771.89
GRAND TOTAL	Jan-Dec	33,200,877		6101.24

Production:Biomass

Assuming a production to biomass ratio of 0.25 generates a value of annual production within the study area of 1525 t.

Consumption:Biomass

Assuming that birds consume 15% of their body mass per day, the annual consumption for the area is 334,043 t, and Q/B is 54.75 yr^{-1}.

Diet

Seabirds within the study area feed at a diversity of trophic levels with most prey being small pelagic fishes, cephalopods and crustaceans (Rice 1992; Montevecchi 1993). However, gannets, the largest breeding seabird species in the region, prey on large pelagic species such as mackerel (*Scomber scombrus*), Atlantic herring (*Clupea harengus*) and short-finned squid (*Illex illecebrosus*) that are the same sizes as those captured by commercial fisheries (Montevecchi *et al.* 1988b). Storm-petrels, the smallest and most abundant breeding species in region, feed primarily on myctophids and crustaceans (amphipods, euphausids) in deep shelf and inshore waters (Montevecchi *et al.* 1992). Dovekies, the smallest seabird species that occurs in the region but breeds outside of it, is primarily a planktivore (Roby *et al.* 1981; Montevecchi *et al.* in prep.). Common murres, gannets, puffins, razorbills, gulls, shearwaters and fulmars feed on capelin that is in the same range of sizes as those exploited by the commercial fishery. Common murres feed their chicks on an almost exclusive diet of female capelin, most of which are gravid (Montevecchi and Myers unpubl. data). Common eiders and scoters prey extensively on blue mussel (*Mytilus edulis*) (Goudie and Ankney 1989). Dietary proportions for all seabird species combined (Table 2b) are extrapolated and estimated from Goudie and Ankney (1989), Cairns *et al.* (1990), Montevecchi *et al.* (1992) and Montevecchi and Myers (1997).

5 & 6. Cod (Lilly, Bundy, Shelton and Dalley)

Background

The Atlantic cod (*Gadus morhua*) has provided Atlantic Canada's most important fishery resource for the last 400 years (Templeman 1966; Lear and Parsons 1993). Within the study area two stocks are recognised for assessment purposes, one in the north in 2J3KL (the "northern" cod) and one on southern Grand Bank in 3NO. Unexploited biomass may have been as high as four million tons. During the late 1950s and 1960s, the catches by distant water fleets increased dramatically and both stocks declined to low levels by the mid to late 1970s. There was some recovery in the early 1980s and the 1985-1987 period was one of relative stability in stock size and catches (Stansbury *et al.* 1995, Shelton *et al.* 1996b). Both stocks declined to very low levels in the late 1980s and early 1990s. The Atlantic cod has long been regarded as a major component of the Newfoundland-Labrador ecosystem.

For this modelling exercise, the Atlantic cod are split into adults and juveniles, or large and small fish, with the division at 35 cm. This is approximately the size at which cod become more piscivorous. It is also the approximate size of first capture in the commercial fishery, so that the > 35 cm group represents the exploitable biomass. However, the split at 35 cm is too low for an effective division into immatures and matures, since the size of 50% maturity in 1985-1987 was around 41-42 cm for males and 50-51 cm for females (Shelton *et al.* 1996b). Only about 62% of the fish in the > 35 cm group are mature. For the purposes of this exercise, it is assumed that fish ≤ 35 cm in length are of ages 2 and less, and fish > 35 cm are 3+.

Catch

Cod > 35 cm

The average total catch of cod in Divisions 2J3KL and Divisions 3NO for the period 1985-1987 was calculated from data in Shelton *et al.* (1996b) and Stansbury *et al.* (1995) to be 289,031 t. To this is added the discarded catch of 9, 563 t of cod from the northern cod and shrimp offshore fisheries (Kulka 1997). The total mean annual catch of cod in 1985-1987 is 298,594 t, or 0.603 $t \cdot km^{-2}$.

Cod ≤ 35 cm

There was an estimated mean annual discarded catch of 1.25 t in the Northern cod and shrimp offshore fisheries (Kulka 1997).

Biomass

Cod > 35 cm

The biomass of 3+ cod is based on ADAPT estimates of cod biomass at the beginning of the year (1985-1988) reported in Shelton *et al.* (1996b) and Stansbury *et al.* (1995). The average biomass of age 3+ cod in the study area during the period 1985-1987 was calculated as 1,011,907 t, or 2.044 $t \cdot km^{-2}$.

Cod ≤ 35 cm

The biomass of the 0, 1 and 2 year olds was estimated from the mean number of 3 year olds on January 1. Averaged over 1986-1988, this was 224,394 x 10^3 individuals. Assuming an annual instantaneous rate of natural mortality of 0.6, since young fish are likely to have a higher natural mortality rate than older fish, and assuming catches are inconsequential, this gives 302,901 x 10^3 2 year olds and 551,921 x 10^3 1 year olds in mid-year and 865,584 x 10^3 0 year olds at the start of the third quarter. Assuming a mean body weight of 0.003, 0.025 and 0.100 kg for cod of ages 0-2 respectively, this gives an average biomass of 46,685 t of age 0-2 cod in the study area, or 0.094 $t \cdot km^{-2}$. This estimate was relatively insensitive to the value used for the annual instantaneous rate of natural mortality, when $M < 1$.

Production:Biomass

Cod > 35 cm

P/B was estimated from a catch curve analysis of RV groundfish survey data from 2J3KL for the years 1983-1988. The estimates of total mortality (slopes of the regression lines fitted to the downward slope of the catch curve) for different year combinations are shown in Table 6. In each case, the line is fitted to the combined data points for each year combination. The best fit occurs when the 1986 year is omitted, due to the anomalously high catch rates in that year (Table 6, Fig. 3). The value of 0.651 yr^{-1} is taken to represent the P/B ratio of cod in 1985-1987. It is equivalent to an annual production of 658,752 t.

Table 6. Results of catch curve analysis of northern cod.

	1983-1988	1985-1987	1984/1985/1987
Z =	0.648	0.646	0.651
R^2	0.894	0.881	0.925

Cod ≤ 35 cm

The P/B ratio for juvenile cod is assumed to be equivalent to the total mortality assumed above in the backcalculation of numbers at age from age 3. The mean P/B is therefore 0.6 yr^{-1}, and the annual production is 28,011 t.

Consumption:Biomass

Cod > 35 cm

Consumption estimates of Atlantic cod in the literature are highly variable. Schulz (1990) compared annual consumption rates estimated for cod from different ICES areas by age. These varied by as much as a factor of 4. There are few studies in Canadian waters which can be used here. Lilly *et al.* (1981) estimated consumption by cod, on the basis of an estimated production (mean number at age times somatic growth at age times reproductive growth at age) and a factor equivalent to gross efficiency, to estimate the consumption required to support this production. Mean Q/B estimates for 1980-81 in 2J3KL were 1.58 to 3.16 yr^{-1} and in 3NO were 2.2 to 4.4 yr^{-1}, depending on whether the gross growth efficiency was taken as 0.2 or 0.1.

Waiwood *et al.* (1980) estimated consumption by cod at age in the southern Gulf of St. Lawrence in 1979 from stomach contents and application of the Ursin fish growth theory. The mean Q/B estimate for 3+ age groups was 2.14 yr^{-1}.

Published values of Q/B in Pauly (1989) range from 1.41 yr^{-1} (north of Norway) to 2.19 yr^{-1} (Georges Bank). There is no clear rationale for using any of the above estimates and all are approximate. Lilly *et al.* (1981) estimates using a GE of 0.1 may be too high, and in any case would be equivalent to applying a GE of 0.1 or 0.2 to the production estimated above. This would give a Q/B of 6.51 yr^{-1} when GE = 0.1, 3.255 yr^{-1} when GE = 0.2 or 4.34 yr^{-1} when GE = 0.15. Again, these estimates are high compared to literature values and the Waiwood *et al.* (1980) estimate.

A range of Q/B values was used. It is assumed that GE is not less than 0.15, and that Q/B is in the range of 2.14 to 4.34 yr^{-1}. This is equivalent to an annual consumption between 2,165,481 t and 4,391,676 t. A mid-point Q/B of 3.24 yr^{-1}, equivalent to a consumption of 3,278,579 t, was used.

Cod ≤ 35 cm

Using the data in Waiwood *et al.* (1980), the Q/B for this size group is 8.18 yr^{-1}. Assuming a gross growth efficiency of 0.15, Q/B is 4 yr^{-1}. Consumption per unit biomass is likely to be greater in smaller fish. Therefore this range is possible. Total annual consumption would be 186,739 to 381,882 t. A mid-point Q/B of 6.09 yr^{-1}, equivalent to a consumption of 284,311 t, was used.

Diet

Cod > 35 cm

Stomach content data are available from stomach collections during Canadian resource assessment bottom-trawl surveys in Divisions 3L, 3N and 3O during spring (1985-1987), Divisions 2J, 3K and 3L in the autumn (1985-1987), and special surveys in Division 3L in the winter (1985-1986) and summer (1985). All sampling was length-stratified. A portion of the cod in 2J, 3K and 3L are landward of the surveys throughout the year. It is assumed here that this portion is small and may be ignored as a separate entity. In addition, some of the cod which overwinter offshore move into shallow coastal waters in the late spring and early summer and return offshore in the autumn. There was very little sampling inshore in 1985-1987, but weekly sampling of the commercial fishery was conducted at Bonavista in northern 3L in 1983 and 1984, and the data collected at this location from June to August are assumed to be representative of the summer inshore diet of cod all along the coast. It is further assumed (with little support) that 50% of the cod in 2J, 3K and 3L participate in the inshore-offshore migration. For simplicity, an annual diet was estimated for each of three areas (3L alone, 2J and 3K combined, and 3N and 3O combined) and then the diets from these three areas were combined to represent the diet of cod in 2J3KLNO.

The method by which the various samples were combined is explained in the diet tables. Diets for Division 3L by season and in total are provided in Appendix 2, Table 1a. Diets for Divisions 2J and 3K combined, Divisions 3N and 3O combined, and then all Divisions combined are provided in Appendix 2, Table 1b. It must be recognized that seasonal coverage is weak, except in Division 3L in 1985, and sampling of coastal waters landward of the area covered by the bottom-trawl surveys is especially weak. In addition, the diets have not been appropriately adjusted for variability in population numbers at length and for variability in digestive rate associated with prey type and temperature.

Additional information on the diet of cod in the study area may be found in Lilly (1984, 1987, 1991).

Cod ≤ 35 cm

The diet of small cod in the offshore was determined as described above for large cod. The diet of small cod in the inshore could not be obtained from sampling the commercial fishery, as had the diet of large cod, because small (≤ 35 cm) cod are not landed by the fishery. However, observations of stomach contents of small cod are available from individuals caught in pelagic traps set for research purposes at two sites in Division 3K and two sites in Division 3L in 1992-1994. Data from all sites and years were combined and divided into two groups by cod length (< 16 cm and ≥ 16 cm). The frequencies of occurrence of the various prey categories were summed, and the frequency of occurrence of each category was expressed as a percentage of the total. It was then assumed that this number was also appropriate as a percentage by weight. The values for the two size-groups were averaged to yield the inshore diet.

The method by which the various samples were combined is explained in the diet tables.

Diets for Division 3L by season and in total are provided in Appendix 2, Table 2a. Diets for Divisions 2J and 3K combined, Divisions 3N and 3O combined, and then all Divisions combined are provided in Appendix 2, Table 2b. It must be recognized that the data available for small cod may be less appropriate than that available for large cod. A large but unknown portion of small cod in Divisions 2J, 3K and 3L reside in the inshore and gradually move offshore at ages 1-3. The diet of small cod in inshore waters has received little attention. In addition, the bottom-trawl employed in 1985-1987 was very poor at sampling those small cod that were offshore, and the data may underrepresent the contribution by the smaller individuals within the <35 cm range.

7 & 8. Greenland halibut (Morgan, Brodie, Bowering and Lilly)

Background

Greenland halibut (*Reinhardtius hippoglossoides*) is a deep water flatfish, usually found at bottom temperatures from -0.5 to 3° C, in the North Atlantic and the North Pacific. In the northwest Atlantic, Greenland halibut are distributed from Arctic regions to Georges Bank, but are most abundant in deeper waters from northern Labrador to the Grand Bank (Bowering 1983).

The main biomass of Greenland halibut within the study area is in NAFO Divisions 2J3KL. An inshore gillnet fishery began in the 1960s, and as catches declined in various bays, the fishery moved offshore to the deepwater channels between the banks. Catches hovered around 30,000 t during the 1970s and decreased gradually during the 1980s. Since the early 1990s, catches have risen steeply, reflecting a new intense fishery in the deepwater areas in 3LM (Brodie *et al.* 1997). However, catches have since declined to around 15,000-20,000 t. There was little or no catch in Divisions 3NO during the mid-1980s.

Greenland halibut were split into adults and juveniles, or large and small fish. Greenland halibut> 40 cm in length are equivalent to 6+ fish (Brodie 1991). Fish ≤ 40 cm in length, essentially juveniles, are regarded as the 0 to 5 year olds. This is the size which approximately corresponds with the size of first capture (Brodie 1991). The main ontogenic change in diet occurs when Greenland halibut are about 20 cm (Bowering and Lilly 1992), and they mature at lengths 63-98 cm for females and 51-96 cm for males (Morgan and Bowering 1995). Thus the 3 criteria for demarcating small or juvenile fish from large or adult fish occur at different sizes and ages. The 40 cm size category was chosen because it splits the biomass into exploitable and non-exploitable biomass (C. Walters, *pers. comm.*) and it is a useful size to split Greenland halibut in terms of their availability as prey.

Catch

Estimates of catch were obtained from a compilation of landings (Brodie *et al.* 1997) and from by-catch data from the shrimp fishery, (D. Kulka, *pers. comm*, unpublished data). The catch was divided into the two size groups using biomass-at-age data in Bowering and Brodie (1988).

Greenland halibut > 40 cm

Most (98 %) of the Greenland halibut catch is greater than 40 cm for the period 1985-87. This gives a total of 17,481 t, or .035 t·km^{-2}, 50% of which was taken in 2J, 30% in 3K and 20% in 3L. Catches from 3NO were very small.

Greenland halibut ≤ 40 cm

Only 2% of the catch was 40 cm or less, giving an annual catch of 373 t. However, it is assumed that the average by-catch of 408.5 t of Greenland halibut in the shrimp fishery during 1985 to 1987 was composed of Greenland halibut ≤ 40 cm. The total catch then is 782 t, 0.002 t·km^{-2}.

Biomass

Campelen converted numbers and biomass-at-age survey estimates for 2J3K were used as the basis for the biomass estimate (DFO unpublished data). The ratio of Campelen number-at-age to Engels number-at-age for 2J3K was used to raise the Engels 3L estimates to Campelen values. The biomass in 3NO was assumed to be negligible in 1985-1987. Numbers were converted to biomass using the age-length-weight data in Brodie (1991) and the length-weight relationship in Bowering and Stansbury (1984).

Greenland halibut > 40 cm

The biomass of Greenland halibut > 40 cm was estimated as 172,485 t or 0.348 t·km^{-2} for 2J3KLNO.

Greenland halibut ≤ 40 cm

The Campelen estimate of biomass of young Greenland halibut was 65,006 t. Biomass was also estimated by back-calculating from the number of 6 year olds, assuming a natural mortality of 0.2 on the 3-6 year olds and a natural mortality of 0.6 on the 0-2 year olds. This gave a biomass estimate of 81,813 t. These estimates are similar, although the Campelen estimate is an under-estimate. The higher estimate of 81,813 t, 0.165 t·km^{-2} is used here.

Production:Biomass

Greenland halibut > 40 cm

Catch curve analysis of numbers-at-age from the RV survey data gave a total mortality and therefore P/B estimate of 0.719 yr^{-1}. The fit of the estimated data to the observed was quite good, with $R^2 = 0.897$. Production of Greenland halibut was also estimated using the assumption that production is equivalent to the product of natural mortality and biomass plus the catch. This method, assuming a natural mortality of 0.2 yr^{-1}, gave an average annual production of 55,097 t, and a P/B estimate of 0.296 yr^{-1}. The difference between the two estimates is quite large. The first is quite high and overestimates the mortality of the 13-17 year olds. This is because older ages are underestimated in the trawl surveys (their selection curve is domed), and Z estimates from catch curves are inflated. It is suggested that a range of values be used, from 0.296 to 0.719 yr^{-1}. This is equivalent to an annual production in the range of 55,097 to 124,053 t. A midpoint of 0.508 yr^{-1} was used.

Greenland halibut ≤ 40 cm

It is assumed that the P/B of the young Greenland halibut is equivalent to the weighted natural mortality y with age, used in the back-calculation to estimate biomass. This gives a P/B estimate of 0.247 yr^{-1} and a total annual production of 18,678 t.

Consumption:Biomass

Food consumption by Greenland halibut was examined by Chumakov and Podrazhanskaya (1986) on the shelf and slope areas of the Northwest Atlantic from Davis Strait to eastern Newfoundland. From 76,700 stomachs taken during surveys in 1969-81, the daily food requirements were found to range from 1.2% of body weight at age 5 to 0.5% at ages 14-17 years. These data were used to estimate consumption rates for both size groups of Greenland halibut.

Greenland halibut > 40 cm

A weighted mean, using relative proportions of biomass-at-age for 6 to 20 year olds, was calculated from the daily food requirements. This gave an annual Q/B estimate of 1.478 yr^{-1}, assuming that Greenland halibut feed for half the year (Chumakov and Podrazhanskaya 1986), or a total annual consumption of 254,722 t.

Greenland halibut ≤ 40 cm

In order to estimate consumption of the younger, smaller fish, it was assumed that the log linear relationship seen in consumption with age for 5 to 17 year old Greenland halibut also applied to 0 to 5 year old fish. The natural log of consumption was regressed against natural log of age, and the regression estimate used to estimate consumption for the 0 to 5 year olds, ($R^2 = 0.99$). Q/B estimates ranged from 5.1 for 4 year olds to 15.4 for 1 year olds. A weighted mean, using the biomass-at-age estimated by back-calculation above, gave a mean annual Q/B of 3.401 yr^{-1} and an annual consumption of 278,054 t.

Diet

Stomach content data are available from stomach collections during Canadian resource assessment bottom-trawl surveys in Divisions 2J and 3K in the autumn (1985-1987) and seasonal surveys in Division 3L during 1985. The sampling in 2J and 3K was conducted to 1000 m. However, the sampling in 3L went only to 366 m, so the information from 3L is representative of the relatively shallow water and is probably less representative of the larger fish, which tend to be in the deeper water. All sampling was length-stratified. It is assumed here that relatively few fish were in 3NO, and their diet is ignored.

Additional information on the diet of Greenland halibut in the study area may be found in Bowering and Lilly (1992) and Rodríguez-Marín *et al.* (1995).

Greenland halibut > 40 cm

The method by which the various samples were combined is explained in Appendix 2, Table 3. The diets have not been appropriately adjusted for variability in population numbers at length and for variability in digestive rate associated with prey type and temperature.

Greenland halibut ≤ 40 cm
The method by which the various samples were combined is explained in Appendix 2, Table 4.

9, 10. American plaice (Morgan, Brodie, Bundy, Lilly and Walsh)

Background

American plaice (*Hippoglossoides platessoides*) has a widespread distribution, occurring on both sides of the Atlantic. It is a bottom dwelling flatfish, and in the western Atlantic occurs from the Arctic to USA waters. The study area contains a portion of the 2+3K stock and the 3LNO stock. The main fishery on Grand Bank in 3LNO has been exploited since the late 1940s. It was basically a Canadian fishery until the 1960s when other countries also started to fish for American plaice (Pitt 1971). Catches peaked in 1967, then fell until the mid to late 1970s when there was a plateau at around 50,000 t. The mid-1980s saw a small peak around 60,000 t, but since then catches have declined. Biomass estimates show a similar trend. In 1994 there was no directed fishey and since 1995 there has been a full moratorium on the 3LNO American plaice fishery (Morgan *et al.* 1997).

The American plaice were split into fish ≤ 35 cm and fish >35 cm in length. This is the length at which there are significant changes in the diet (see below). In addition, the length of 35 cm is approximately the length at maturity of female plaice and the length at first capture. The length of 35 cm corresponds to an age of approximately 7 years, although this varies considerably by area and sex.

Catch

The average catch for the period 1985-1987 in 3LNO was 57,931 t (Morgan *et al.* 1997) and in 2J3K was 1611 t (Brodie *et al.* 1993). Discards from other Newfoundland fisheries increased these totals by 109 t in 2J3K and 1972 t in 3LNO during 1985-1987 (Kulka 1986). In addition, there was a bycatch of 67.9 t from the shrimp fishery (D. Kulka, *pers. comm.*). This makes a total annual catch of 61,691 t.

This total was divided between the two size groups of American plaice using commercial biomass-at-length data in Brodie (1986, 1987) for the Canadian fleet and numbers, weight, and length in the commercial catch for the Spanish fleet in 1987 (Brodie 1988). These data are for 3LNO and it is assumed that they also apply to the smaller fishery in 2J3K.

American plaice > 35 cm
About 94 % the Canadian catch and 64% of the Spanish catch of American plaice was greater than 35 cm. It is assumed that all discards are less then 35 cm, and the other fleets' catch was the same as the Spanish catch. This gives a total catch of American plaice > 35 cm of 49,454 t, 0.1 $t \cdot km^{-2}$.

American plaice ≤ 35 cm
About 6 % the Canadian catch and 36 % of the Spanish catch of American plaice was 35 cm

or less. Assuming that all discards were 35 cm or less, the total catch was 12,237 t, 0.025 $t{\cdot}km^2$.

Biomass

Biomass was estimated from Campelen converted estimates for 1985-1987. At the time of writing, these estimates were available as numbers-at-length for the 3LNO stock only. These were converted to biomass-at-length using a weight-length relationship (Brodie 1985). The biomass in 2J3K was estimated by applying the Engels to Campelen conversion from 3LNO to the numbers at age in 2J3K and then applying the weight-length relationship. The results are shown in Table 7.

Table 7. Mean 1985-1987 American plaice biomass (t) (Campelen converted) in 2J3K and 3LNO.

Area/ Length group	*2J3K*	*3LNO*	*2J3KLNO*	*2J3KLNO $t{\cdot}km^{-2}$*
> 35 cm	57936	423269	481205	0.972
≤ 35 cm	76901	311062	387963	0.784
Total	134837	734331	869168	1.756

Production:Biomass

American plaice > 35 cm

It is assumed that P/B=Z. Z was estimated from a catch curve analysis of Campelen converted American plaice survey data from 3LNO for the years 1985-1987. The catch curve was fitted for ages 7 to 17 (Fig. 4). The slope of the regression lines fitted to the downward slope of the catch curve is -0.538, and $R^2 = 0.988$. The total mortality, and therefore P/B estimated from the catch curve, is thus 0.538 yr^{-1}.

American plaice ≤ 35cm

The total mortality of the small length groups is not known. In the absence of other information, it is assumed that their production is equivalent to biomass multiplied by natural mortality plus the catch. This gives a production of 300,960 t and a P/B of 0.625 yr^{-1}.

Consumption:Biomass

American plaice > 35 cm

Consumption was estimated from daily ration data for American plaice on the tail of the Grand Bank (Zamarro 1992). The diet of American plaice here is comprised mainly of the sand lance (*Ammodytus dubius*), brittle stars and capelin (*Mallotus villosus*). Zamarro estimated daily ration using the model of Elliot and Persson (1978). American place were collected from July 1987 to December 1989, thus providing an annual cycle of estimates, at around the time period of interest. Monthly daily rations were taken from Figure 13 in Zamarro (1992). From these data, the mean annual Q/B ratio was estimated as 1.262 yr^{-1}

American plaice ≤ 35cm

Consumption of juvenile American plaice was estimated from data presented in MacDonald and Waiwood (1987) for American plaice size 14-31 cm in length. Sampling was conducted in May in Passamaquoddy Bay, New Brunswick, where bottom temperatures were 5.5 - 6.1 C. The major prey of young American plaice in this area are amphipods and polychaetes. The authors estimated a daily ration of 1.28% of body weight per day. This translates to a Q/B ratio of 4.67 yr^{-1} if feeding is constant throughout the year. Adult American plaice showed a peak in feeding activity during May on the tail of the Grand Bank (Zamarro 1992). The feeding cycle of juvenile American plaice is not known, but if it is assumed to be the same as the adults and assuming a peak daily ration of 1.28%, Q/B is 2.8 yr^{-1}. It is suggested that both estimates should be used to described a likely range of Q/B values of 2.8 to 4.672 yr^{-1} for the young American plaice. A midpoint of 3.736 yr^{-1} was used.

Diet

Stomach content data are available from stomach collections made during Canadian resource assessment bottom-trawl surveys in Divisions 2J and 3K in autumn 1977-1978, seasonal surveys in Division 3L during 1985, a spring survey in Divisions 3NO in spring 1984 and juvenile flatfish surveys in 3NO in summer 1985-1986 (Appendix 2, Tables 5a,b, 6a,b).

The sample sizes in 2J and 3K were very small. In addition, the autumn 1977 sample in Division 2J had a high proportion of Greenland halibut <= 40 cm. This was probably anomalous, and an arbitrary adjustment has been made to the final 2J3KLNO diet. In addition, sampling of cod stomachs has shown that the quantity of capelin in Divisions 2J and 3K in autumn 1978 was very low (Lilly 1991). For these and other reasons, the data available for 2J3K probably do not well represent the diet in that area in 1985-1987, but it is thought that it is more appropriate to include the data that are available than to ignore the area altogether.

The data for 3NO in the summers of 1985 and 1986 are from surveys directed toward juvenile flatfish, and do not cover the whole of 3NO.

Additional information on the diet of American plaice in the study area may be found in Pitt (1973) and Zamarro (1992).

American plaice > 35 cm

The method by which the various samples were combined is explained in the diet tables. Diets for Divisions 2J and 3K and Division 3L (by season and in total) are provided in Appendix 2, Table 5a. Diets for Divisions 3N and 3O combined, and all then Divisions combined are provided in Appendix 2, Table 5b.

American plaice ≤ 35 cm

The method by which the various samples were combined is explained in the diet tables. Diets for Divisions 2J and 3K and Division 3L (by season and in total) are provided in Appendix 2, Table 6a. Diets for Divisions 3N and 3O combined, and then all Divisions combined are provided in Appendix 2, Table 6b.

11. Flounders (Bowering, Bundy, Walsh and Lilly)

Background

The Flounders consist of yellowtail flounder (*Limanda ferruginea*), witch flounder (*Glyptocephalus cynoglossus*) and winter flounder (*Pseudopleuronectes americanus*). The flounders were grouped together on the basis of the similarity in their feeding behaviour. All are sedentary demersal flatfish that have small mouths and feed on benthic invertebrates.

Yellowtail flounder dominate the group in terms of biomass. Their distribution ranges from Labrador in the north to Cape Hatteras, North Carolina, in the south. Only one stock, Division 3LNO, lies within the study area. There has been a fishery for yellowtail flounder since the 1960s. Catches peaked in the early 1970s and than again in the mid 1980s (Walsh *et al.* 1997).

Witch flounder has a more northerly distribution. Two stocks occur within the study area, in Divisions 2J3KL and Division 3NO. Witch flounder is a deep water species. During the model time period 1985-1987 the R.V. survey was mainly in shallow waters, which means that stock sizes will probably be underestimated. There has been a fishery for witch flounder since the 1960s in 2J3KL and since the early 1970s in 3NO. Both had high catches in the mid 1970s, but the 2J3KL stock has since declined, and there has been no directed Canadian fishery since 1994 (Bowering 1997). There was a high peak in catches in the 3NO stock in the mid 1980s, but this stock also declined severely (Bowering and Orr 1997).

Winter flounder is an inshore shallow-water species that undergoes fairly regular inshore-offshore migrations, moving offshore in the winter and inshore in the summer. Its distribution ranges from the southern Labrador shelf to the Gulf of Maine (Scott and Scott 1988). It is of little commercial importance.

Catch

The mean annual catch for the period 1985-1987 was calculated for yellowtail flounder from data in Walsh *et al.* (1997), for witch flounder from data in Bowering (1997) and Bowering and Orr (1997) and for winter flounder from Anon (1987, 1989, 1990) (Table 8). Also given are the discarded catches estimated for 1985 (Kulka 1986). The mean flounder catch for 1985-1987 was 39,273 t, or 0.079 $t \cdot km^{-2}$.

Table 8. Mean annual catch (tonnes) for the 3 species of flounder, individually and combined.

	Yellowtail Flounder	*Witch Flounder*	*Winter Flounder*	*Flounders*
2J3KL		3798	1280	5078
3LNO	25151			
3NO		8499	10	33660
Discards	516	20		535
Total	25667	12317	1290	39273

Biomass

Mean biomass of yellowtail and witch flounder was estimated from Campelen converted Engels RV data for 1985-1987. Yellowtail data came from Walsh *et al.* (1998) and witch data from Bowering (1998).

For yellowtail flounder, RV survey data only sampled 4 to 11 year olds. In order to obtain a biomass estimate for the whole population, numbers were backcalculated from numbers at age 7 to age 0, and the biomass of age 0 to 6 added to the 7+ Campelen biomass. A natural mortality of 0.3 (Pitt 1975) was assumed for age groups 3 to 6 and a natural mortality of 0.6 for age groups 0 to 2. Biomass will be slightly underestimated since there is a commercial catch of 4 to 6 year olds. Backcalculated numbers-at-age were multiplied by mean weights-at-age for the 0 to 6 year olds (DFO unpublished data). This backcalculation produced a biomass of yellowtail flounder 0 to 6 years old of 162,304 t. The 7+ Campelen converted biomass was 105,490 t (Table 9).

The mean Campelen converted witch flounder biomass for 1985-1987 was 53,975 t. Again, this figure only includes the older age groups that are selected by the gear. In order to estimate the biomass of young fish, it was assumed that the ratio of young fish to selected fish was the same as for yellowtail flounder. Thus, the biomass estimate for age 0 to 6 fish is 83,045 t.

There are no RV survey estimates of winter flounder because it is an inshore species. An approximate biomass was estimated by assuming that the exploitation rate is low, say 10%. This exploitation rate was applied to the highest catch during the time period (2,464 t in 1987), giving a biomass estimate of 24,640 t for 1985-1987.

The 1985-1987 biomass estimate for the flounders is 429,454 t, 0.868 km^{-2} (Table 9).

Table 9. Mean annual biomass estimates (tonnes) for the 3 species of flounder, individually and combined.

	Yellowtail Flounder	*Witch Flounder*	*Winter Flounder*	*Flounders*
Campelen Biomass, age 7+	105,490	53,975		159,465
Backcalculated Biomass, age 0-6	162,304	83,045		245,349
B from catch assumption			24,640	24,640
Total	267,794	137,020	24,640	429,454

Production:Biomass

In order to estimate P/B, catch curve analysis was first used to estimate total mortality for yellowtail and witch flounders. However, in both cases, the analysis was non-conclusive. Numbers caught at age increase until age 8 or 9, and then rapidly decrease after age 10. The 2 or 3 age classes that would appear to be fully selected by the gear are not representative of the population and indicate very high mortalities. This method was deemed unsuitable. Instead, it was assumed that production was equivalent to biomass multiplied by natural mortality and the catch added to the product. Natural mortality was assumed to be 0.3. This gives a total annual production of 106,005 t for yellowtail flounder and 53,423 t for witch flounder. Since data for winter flounder are poor, its production was not estimated. P/B ratios are 0.396 yr^{-1} and 0.390 yr^{-1} for the two species, giving an average of 0.394 yr^{-1} for the flounder group, and a total flounder production of 169,132 t.

Consumption:Biomass

Grosslein *et al.* (1980) estimated a Q/B of 4.6 for yellowtail flounder on George's Bank, for 1963-1972, weighted over all ages. Alternatively, assuming a gross growth efficiency of 0.15 (Collie 1987), Q/B would equal 2.639 yr^{-1}. This same assumption was made for the witch flounder, giving a Q/B of 2.599 yr^{-1}. No estimate was made for the winter flounder. Since all estimates are only approximations, a range of Q/B values, 2.599 – 4.6 yr^{-1}, encompassing these estimates was used. Thus annual consumption from 1985 to 1987 was 734,416 to 1,082,792 t. A midpoint of 3.60 was used as the initial input value for Q/B.

Diet

The diet of winter flounder (Appendix 2, Table 7a) was compiled from Keats (1990) and Kennedy and Steele (1971). The sampling in both studies was very limited in space. The diet of yellowtail flounder (Appendix 2, Table 7b) was taken from Pitt (1976), who reported on sampling on Grand Bank. The diet of witch flounder (Appendix 2, Table 7b) was taken from Rae (1969), who reported on sampling from the eastern Atlantic.

The diet of the flounder group (Appendix 2, Table 7b) was an average of the diets of the three species, weighted by their biomasses.

12. Skates (Bundy, Kulka, Lilly and Methven)

Background

Skates, of the family Rajidae, are widely distributed through the study area but are most abundant on Grand Bank. There are 8 to 10 species, but 90% of the RV survey biomass in 3LNO is comprised of the thorny skate (*Raja radiata*). The smooth skate (*R. senta*) accounts for 5% of the biomass and other species, such as winter skate (*R. ocellata*), spinytail skate (*R. spinicauda*), and barndoor skate (*R. laevis*) make up the other 5%. (Kulka *et al.* 1996). The thorny skate are fairly long-lived, at least 20 years (Templeman 1984), and are thought to be sedentary (Kulka *et al.* 1996). They deposit large leathery egg cases which contain a single embryo. A female may lay between 6 and 40 of these per year and egg size is related to parent size. The thorny skate is a bentho-pelagic species and is taken as the representative species for skate group.

Catch

There was limited interest in skate fishing in the mid-1980s. (This changed in the 1990s when attention was switched to non-traditional species as a consequence of moratoria on traditional species.) The bulk (61%) of the mean annual catch of 14,846 t for 1985-1987 came from 3N and 23% from 3L (NAFO Statistical Bulletins Anon. 1987, 1989, 1990). In addition, Kulka *et al.* (1996) estimated that another 3000-4000 t of skate were caught as by-catch in other fisheries during the 1980s. This would put the total annual skate catch at around 18,346 t, or

0.037 t·km^{-2}, assuming 3,500 t of by-catch. Kulka *et al.* (1996) also note that the accuracy of the skate catch statistics is questionable, and that up to 60% of reported skate catches may have been misreported catches of other species.

Biomass

Annual biomass estimates of the thorny skate for the period 1985-1987 were obtained from Engels R/V data for Divisions 2J3KLNO for the 1985-1987 period (Kulka *et al.* 1996; DFO, unpublished data). The average biomass was calculated to be 116,170 t. This was raised to Campelen equivalent units as follows. The mean biomass in the last 3 years of the Engels RV survey (1992-1994) was compared to the mean biomass in the second two years of Campelen RV survey 1996-1997. The ratio between the 1992/1994 Engels biomass estimate and the 1996/1997 Campelen biomass estimate was used to raise the 1985-1987 Engels biomass estimate. The raising factor was 2.2, making the mean annual biomass 255,979 t, or 0.517 t·km^{-2}.

Production:Biomass

In the absence of information on total mortality of skates in this region and information on catch at age with which to estimate total mortality, it was assumed that production is equivalent to biomass multiplied by natural mortality and the catch added to the product. The natural mortality estimate of 0.214 (Simon and Frank 1996) was used. This gives a total production of 73,126 t and a P/B of 0.286 yr^{-1}.

Consumption:Biomass

Consumption rates are not known for the thorny skate in the area. However, studies in two other areas have estimated very similar consumption:biomass values for *R radiata*. Vinther (1989) estimated a Q/B of 2.865 for *R. radiata* in the North Sea, and Dologov (1997) estimated a Q/B of 2.891 for *R. radiata* in the Barents Sea. A mean value of 2.878 was used here, giving a total consumption of 236,669 t.

Diet

The diet of thorny skate is assumed to be representative of the skate group. Thorny skate diet (Appendix 2, Table 8) was modified from data in Templeman (1982).

13. Redfish (Power, Bundy, Lilly and Methven)

Background

Redfish are long-lived, slow growing, semi-pelagic fish that occur in depths from 100 - 700m. Unlike most other marine fish species, redfish are viviparous. Mating occurs in the fall and females release live young from April to July. They reach a commercial age at approximately 8 to 10 years at a length of 25 cm. There are three redfish stocks (2+3K, 3LN and 30) within the study area. The stocks consist of a mixture of *Sebastes mentella* and *S. fasciatus*. There was minimal fishing activity in 3O by the Canadian fleet in 1985 - 1987, although foreign fleets (Russia, Cuba, Japan) did fish in the area.

Catch

The average annual catch for 1985-1987 for 2J3KLNO was calculated as 86,758 tons (Power 1995, 1997, and Power *et al.* 1996 for 2J3K, 3LN and 3O respectively). To this is added 1199 t of discarded redfish from other fisheries (Kulka 1986), making a total of 87,957 t, equivalent to 0.178 $t \cdot km^{-2}$.

Biomass

There is no comprehensive Canadian research survey coverage of the whole area to a depth of 1000 m. Since redfish are deepwater species, deeper waters need to be covered in the survey. There are fall RV data for 2J3K (Power 1995) and Campelen converted estimates of RV survey biomass for 3L in each quarter of 1985 and for the first and fourth quarter of 1986 (Power and Maddock Parsons 1998). There are also Russian bottom trawl survey estimates for the second quarter of 1985 to 1987 for 3L and 3N (Power and Vaskov 1992). The Canadian RV survey coverage of 3O is insufficient to estimate the biomass of redfish because the survey covered waters only to a depth of 367 m during the time period of interest. All the above sources were used to estimate redfish biomass in 2J3KLNO.

The estimation of biomass for 2J3K and 3L was straightforward. The Campelen converted estimates were used to estimate biomass in 3L in 1985 and 1986. The ratio between the Campelen converted data and Engels data in 3L was used to raise the 2J3K biomass estimate to Campelen converted trawlable biomass estimates. The ratio between the Engels and Russian survey estimates (2.37:1) and between the Russian and Campelen estimates (2.87:1) were used to estimate the 3L 1987 biomass and the 3N biomass for 1985-1987.

Since no survey biomass estimates exist for 3O, it was assumed that the exploitation rate in 3O is the same as in 3LN;

$$3O\ Biomass = (3LN\ Biomass/3LN\ catch)*3O\ catch$$

This may underestimate the biomass since it is likely that the exploitation rate of 3O redfish was less than 3LN in the mid 1980s.

The average annual biomass for the study area obtained using this method was 482,379 t, or 0.975 $t \cdot km^{-2}$.

Production:Biomass

The estimate of P/B was first attempted using catch curve analysis of RV survey numbers at age. However, the catch curve analysis did not work well for two reasons: redfish are slow growing and are difficult to age accurately. In addition, RV surveys exhibit considerable variability in estimating relative year class strengths, and selection is dome shaped which means that the mortality of older age groups is overestimated.

Production was calculated as biomass multiplied by natural mortality and the catch added to the product. Natural mortality was assumed to be 0.125, using the mid-range of values estimated by Rikhter (1987). This gives an estimated production of 148,255 t and a P/B ratio of 0.33 yr^{-1}. This seems high for a slow growing, long lived species and it is likely that the biomass estimate is too low.

Consumption: Biomass

Dolgov and Drevetnyak (1990) estimated annual food consumption to biomass ratios for Barents Sea deep-water redfish (*S. mentella*) to vary from 6 for fingerlings down to 1.3 for fish at age 19. This consumption at age data (10+ age groups) was used to estimate consumption of redfish in 2J3KLNO. Relative numbers-at-age in 2J3K (1985-1987) and 3L (1984-1986) (DFO Unpublished data) were multiplied by mean weight-at-age in 2J3K and 3L (1980 - 1997, DFO Unpublished data) to obtain a relative biomass-at-age composition. It is assumed that this is representative of the age structure of the population. Relative biomass-at-age was then multiplied by the annual consumption in each year to obtain a relative total consumption per year. This was divided by the relative biomass, summed over all ages, to obtain Q/B for ages 10+ for 2J3K and 3L. Values ranged from 1.13 to 1.37 yr^{-1} in 2J3K and 1.32 to 1.37 in 3L. The mean consumption was 1.3 yr^{-1}.

However, the average Q/B over all ages would be greater than this. For fingerlings to 6 year olds it ranged from 6 to 2. Thus to allow for the biomass of younger age groups, for which there is no adequate biomass-at-age data, the Q/B was raised to an intermediate estimate of 2 yr^{-1}. This gives a mean average annual consumption of 964,758 t.

Diet

The diet of redfish (Appendix 2, Table 9) was based primarily on Lambert (1960) with minor modifications based on Yanulov (1962) and Konchina (1986).

14. Large Demersal Feeders (Bundy, Lilly and Methven)

Background

The large demersal feeders include white hake (*Urophycis tenuis*), haddock (*Melanogrammus aegelfinnus*), rocklings, grenadiers (Macrouridae), wolffish (*Anarhichas spp.*), eelpouts (Zoarcidae), common lumpfish (*Cyclopterus lumpus*), monkfish (*Lophius americanus*), and Atlantic halibut (*Hippoglossus hippoglossus*). Wolffish were distributed throughout 2J3KLNO in the mid 1980s, but their distribution has since contracted (Kulka and Deblois 1996). White hake distribution was limited to the edge of the southern Grand Bank, basically in 3O, and monkfish distribution was limited to the southern Grand Bank (Kulka and Deblois 1996). None of the large demersal feeders has been well studied in 2J3KLNO and most information comes from other sources. Juvenile large demersal feeders are classified as small demersal feeders, see below.

Catch

Based on the total average catch within the study area of the species listed above for the period 1985-1987 as reported in NAFO Statistical Bulletins (Anon. 1987, 1989, 1990), the average annual catch of large demersal feeders was calculated to be 21,509 t. In addition, there was an average of 94.9 t caught as bycatch in the shrimp fishery during 1985 to 1987 (D. Kulka *pers. comm.*), and 4,285 t discarded in other fisheries (Kulka 1996). The total catch was 25,889 t or 0.052 t·km^{-2}. Haddock, roundnose grenadier (*Coryphaenoides rupestris*) and white hake make up 80% of this total.

Biomass

Annual biomass estimates of the large demersal feeders for the period 1985-1987 were obtained from R/V data for Divisions 2J3KLNO (DFO, unpublished data). The average biomass was calculated to be 133,907 t. This was raised to Campelen equivalent units using the ratio between 1993/1994 Engels biomass estimates for 2J3KLNO and 1996/1997 Campelen biomass estimates. The raising factor was 3.1, making the mean annual biomass 418,173 t, or 0.845 t·km^{-2}.

Production:Biomass

Production was estimated by multiplying the biomass by natural mortality and adding catch. Assuming an instantaneous natural mortality rate of 0.2, this gave a production of 109,524, and a P/B value of 0.262 yr^{-1}.

Consumption:Biomass

Assuming a production to consumption ratio of 0.15, consumption was calculated to be 730,161 t, and a Q/B of 1.747 yr^{-1}.

Diet

The diet of the large demersal feeders is difficult to determine, primarily because the diets of the species within this group are diverse and poorly studied but also because the relative biomasses of the species (or groups) has not yet been determined.

The diet of Atlantic (or striped) wolffish (*Anarhichas lupus*) has been studied in the offshore by Albikovskaya (1983) and Templeman (1985) and in the inshore by Keats *et al.* (1986). Diets of spotted wolffish (*A. minor*) and northern (or broadhead) wolffish (*A. denticulatus*) have been described by Albikovskaya (1983). An attempt to combine the data from these studies into an average diet for wolffish is presented in Appendix 2, Table 10a.
The diet of the several species of grenadiers (Appendix 2, Table 10b) is compiled from the information in Savvatimsky (1989a) for roughhead grenadier, Gushchin and Podrazhanskaya (1983) for roundnose grenadier and Savvatimsky (1989b) for common grenadier. There is additional information for the above three species in Houston and Haedrich (1986). These data are not used because the samples came from a small area (near Carson Canyon on the southeastern slope of Grand Bank).

The diet of white hake (Appendix 2, Table 10c) is compiled from Petrov (1973).

The diet of haddock (Appendix 2, Table 10c) is compiled from Kohler and Fitzgerald (1969) for the Scotian Shelf and Langton and Bowman (1980) for the southwestern Scotian Shelf and New England, with a modification based on Templeman (1965).

The diet of ocean pout (Appendix 2, Table 10d) was reported by Keats *et al.* (1987). This diet may be biased toward echinoderms because the fish were collected on sea urchin grounds. Therefore, the echinoderm portion of the diet has been reduced and the difference arbitrarily spread over other groups to reflect the broader prey spectrum seen in studies to the south (Buzulutskaya 1983; references in Scott and Scott 1988). The diet of other eelpouts is a guess based on notes in Scott and Scott (1988).

The diets of lumpfish and monkfish (Appendix 2, Table 10e) are guesses based on notes in Scott and Scott (1988).

The diet of Atlantic halibut (Appendix 2, Table 10e) is compiled from Kohler (1967).

A composite diet for large demersal feeders (Appendix 2, Table 10e) is derived from an average of the eight species or groups discussed above, with weightings based on a guess of relative biomasses.

15. Small Demersal Feeders (Bundy and Lilly)

Background

The small demersal feeders include gunnels (Pholidae), blennies (Stichaeidae), pouts (*Lycodes*) and wolfeels (*Lycenchelys spp.*), sculpins (Cottidae), alligatorfish (Agonidae), lumpfish (Cyclopteridae, exluding common lumpfish), and seasnails (Liparidae). None of these species were fished commercially in 1985-1987 and little is known about them. This group also includes juvenile large demersal feeders.

Catch

There was no targeted catch of small demersal feeders. However, an average of 44.1 t were caught as by-catch and discarded by the shrimp fishery during this period (Kulka *pers. comm.*).

Biomass

Annual biomass estimates of the small demersal feeders for the period 1985-1987 were obtained from R/V data for Divisions 2J3KLNO (DFO, unpublished data). The average biomass was calculated to be 10,476 t. This was raised to Campelen equivalent units using the ratio between 1993/1994 Engels biomass estimates for 2J3KLNO and 1996/1997 Campelen biomass estimates. The raising factor was 10.7, making the mean annual biomass 112,327 t, or 0.227 $t \cdot km^{-2}$.

Production:Biomass

In the absence of other data, it was assumed that P/B is in the range of 0.2 to 0.4 yr^{-1}, giving an annual production of 22,465 to 44,931 t. A P/B of 0.3 yr^{-1}, equivalent to a production of 33,698 t, was used as an initial input value.

Consumption:Biomass

There are no consumption estimates for the small demersal feeders, so consumption was estimated by assuming a gross growth efficiency of 0.15, giving a Q/B of 1.33 to 2.67 yr^{-1} and an annual consumption of 149,770 to 299,540 t. A mean value of 2.0 yr^{-1}, equivalent to a consumption of 224,655 t, was used as the initial input value.

Diet

There is very little information on the diet of this group. A guess is made (Appendix 2, Table 11) using general information available in Scott and Scott (1988).

16. Capelin (Winters, Carscadden and Lilly)

Background

The capelin (*Mallotus villosus*) is perhaps best known for its spawning behaviour. As juveniles they live offshore, but in 2J3KL they migrate to beaches to spawn during late June and early July (Carscadden and Nakashima 1997). In 3NO, they spawn offshore. Capelin is a short-lived, pelagic species that is an important prey for many species in the ecosystem. In the 1980s, capelin was assessed as 3 stocks (2+3K, 3L and 3NO). Since 1993 capelin in 2+3KL have been treated as one stock. Recruited capelin are considered to be all fish 2 years old and older.

Catch

The fishery for capelin has a variable history (Carscadden and Nakashima 1997). The fishery was once small and domestic, but in the 1970s it expanded to accommodate, at its peak, a 246,000 t foreign offshore fishery. By the late 1970s, however, the stocks declined and fisheries were either closed or quotas severely reduced. Since the late 1970s there has been a domestic inshore fishery for roe-bearing capelin for the Japanese market. The mean catch for the period from 1985-1987 was 62,362 t, or 0.126 $t \cdot km^{-2}$ in 2J3KLNO (NAFO Statistical Bulletins, Anon, 1987, 1989 and 1990).

Biomass

The Canadian groundfish RV survey does not give reliable estimates of capelin biomass or abundance (Carscadden and Nakashima 1997). Capelin is a pelagic species and the RV survey is designed to capture demersal fish species. Instead, biomass estimates that came from acoustic surveys of 2J3K, 3L and 3NO were used (Miller 1992, 1993a, and 1993b). The mean average biomass for the population over the whole area in 1985-1987 was 4,100,000 t. However, this estimate does not include the 0 and 1 year olds. The biomass of these younger groups was estimated by back-calculating from the mean number of 2 years olds (196 billion). Shackell *et al.* (1994), building on the work of Shelton *et al.* (1993), analysed survival rates in 3L capelin by sex and by age. They found that for age 2 capelin, survival rates were not sex specific. Thus a mean of the male and female survival rates for 2 years olds (39.7%) is used here to represent survival of the 0 and 1 year olds (this assumes that all immature fish, age 2 and less, have the same survival rate). So, assuming that there is no catch of 0 and 1 year olds, there would have been 495 billion 1 year olds at mid-year and 992 billion 0 year olds at the start of the fourth quarter. Assuming a mean mid-year body weight of 0.001 kg for the 0 year olds and 0.003 kg for the 1 year olds (Carscadden, *pers. comm.*), the average biomass of capelin younger than age 2 is 2,478,068 t. The total average biomass of all capelin is 6,578,068 t, or 13.289 $t\cdot km^{-2}$, in 2J3KLNO. This estimate is relatively insensitive to the survival rate when survival is high. A high range of survival rates, say between 35 and 90%, produce biomass estimates from 5 to 7 million tons. However, if the survival rate decreases below 25%, the biomass estimates increase exponentially.

Production:Biomass

The production:biomass ratio was assumed to be equivalent to total mortality (Allen 1971). The survival rates in Shackell *et al.* (1994) for capelin in 3L for 1985-1987 were weighted by sex, age and maturity in the population to give a mean survival rate for the population (age 0 to 6) of 31.8 %. This is equivalent to a total mortality rate of 1.145 $year^{-1}$ and a mean annual production of 7,532,502 t.

Consumption:Biomass

There are no consumption rate studies for capelin in Newfoundland waters. However, there are comparative studies from other areas, such as the St. Lawrence Estuary and the Barents Sea. Vesin *et al.* (1981), for example, found the capelin daily ration of zooplankton in the St. Lawrence Estuary and western Gulf of St. Lawrence was approximately 5% of the body weight per day in May-September and around 2.5% in October-November. This is equivalent to an annual Q/B of around 13 $year^{-1}$. These estimates are comparable with the studies of Panasenko (1981) in the Barents Sea who used 3 different methods for analysis of diurnal stomach content and estimated daily consumption rates between 1.4 and 13.7%. The average of 6% body weight per day is equivalent to a Q/B of 11 $year^{-1}$. This estimate pertains to spring when the capelin are putting on fat, and may therefore be an overestimate of the annual consumption rate. Ajiad and Pushchaeva (1992) studied Barents Sea capelin in August 1989 and estimated the consumption rate to be between 1.3 and 2.2%. Based on these studies, it is assumed that the daily consumption rate of capelin in 2J3KLNO is 3% of body weight per day, and that they have an annual feeding period of 7 months (Carscadden *pers. comm.*), giving an annual Q/B of 6.4 $year^{-1}$ and an annual consumption of 42,017,406 t. The consumption rate estimate is very sensitive to the assumed % body weight consumed. For example, 2% body weight per day would be equivalent to a Q/B of 4.3 $year^{-1}$ and 4% a day a Q/B of 8.5 $year^{-1}$.

Diet

The diet of capelin (Appendix 2, Table 12) was compiled from observations on Grand Bank in spring (Kovalyov and Kudrin 1973; Gerasimova 1994) and off Labrador in autumn (Chan and Carscadden 1976).

17. Sand lance (Winters, Bundy, and Lilly)

Background

The sand lance species group is assumed to be all northern sand lance (*Ammodytes dubius*).

Its geographic range extends from West Greenland to Cape Hatteras in the USA. In Newfoundland and Labrador waters, some small populations occur inshore, but most sand lance in the area occur on the plateau of Grand Bank. They are small, semi-demersal fish and are abundant in areas where the bottom substrate consists of sand and fine gravel. They feed pelagically and are similar to capelin in their role as a forage species (Winters 1983). Main predators on the southern Grand Bank are American plaice and cod.

Catch

Sand lance are not commercially fished and there is no recorded catch..

Biomass

Sand lance were very poorly sampled by the RV survey using Engels gear. The mean biomass was estimated as 35 t in 1985-1987 and 31 t in 1992-1994 for 2J3KLNO (DFO, unpublished data). The RV survey using the Campelen gear sampled the sand lance better and the mean biomass in 1996-1997 was 104,091 t (DFO, unpublished data). This is still likely to be an underestimate, for sand lance are considered to be at least as abundant on Grand Bank as capelin, which have a mean biomass of around 300,000 t in 3NO (Miller 1993b). In order to obtain a more realistic biomass estimate, a 2 step method was used. First it was assumed that the biomass of sand lance has not changed between 1985-1987 and 1996-1997; that is, that the 1996-1997 biomass estimate is representative of the model time period. Second, this biomass estimate was raised by a catchability factor. Scott (1971) estimated a catchability of 0.01 for sand lance on the Scotian Shelf using a Yankee # 36 otter trawl. It is assumed that the Campelen gear is ten times as efficient as the Yankee #36 gear at catching sand lance. Thus, the catchability factor is 0.1. Applying this to the Campelen biomass estimate produces a mean annual biomass estimate of 1,040,912 t, or 2.103 $t \cdot km^{-2}$.

Production:Biomass

Winters (1983) estimated the average instantaneous total mortality rate (Z) of sand lance using catch curve analysis based on catches during research vessel surveys. In 1975-1979, when the biomass of cod was approximately 100,000 t, Z was 0.62 yr^{-1}. Z was estimated as 1.15 yr^{-1} from 1968-1974 when cod biomass was approximately 500,000 t. In the mid 1980s, the time period of the model, cod biomass on Grand Bank (Divisions 3LNO) was around 500,000 t (Shelton *et al.* (1996b) and Stansbury *et al.* (1995). It is thought that cod predation on sand lance is a major contributor to sand lance mortality and variability in abundance (Winters 1983). It is assumed that since cod biomass was high in the mid 1980s, mortality on sand lance was also high and that the Z estimate of 1.15 yr^{-1} applies. Thus, assuming P/B=Z (Allen 1971), P/B = 1.15 yr^{-1}, and annual production is 1,197,049 t.

Consumption:Biomass

In the absence of information on consumption by sand lance, it was assumed that the gross growth efficiency, the ratio between production and consumption, was 0.15. Thus, consumption was calculated as 7,980,325 t and Q/B was 7.667 yr^{-1}.

Diet

The diet of sand lance (Appendix 2, Table 13) was taken from Scott (1973), who examined fish caught on the Scotian Shelf.

18. Arctic cod (Lilly and Bundy)

Background

The Arctic cod (*Boreogadus saida*) have a circumpolar distribution. In the northwest Atlantic, they are found from Arctic waters in the north as far south as the southern Gulf of St. Lawrence (Scott and Scott 1988). They are semi-demersal and feed mainly on pelagic invertebrates. The Arctic cod, like capelin, is an important forage species and link in the transfer of energy from zooplankton to other fish, sea mammals and sea birds (Lilly *et al.* 1994). There is no commercial fishery for Arctic cod and therefore no assessment within the study area. As a consequence, the information on this species is poor.

Catch

Arctic cod is not commercially fished. There was a small by-catch of 30 t in the shrimp fishery during 1985-1987 (D. Kulka, *pers. comm.*), but this is not regarded here.

Biomass

Like capelin, the Arctic cod is inadequately sampled by the RV trawl surveys. The mean biomass estimated from these data for 1985 to 1987 in 2J3KLNO was 2, 819 t (Lilly *et al.* 1994 and DFO, unpublished data). In order to obtain a more realistic estimate of total biomass, capelin biomass data were used to develop a raising factor. The ratio between capelin RV survey biomass and capelin acoustic biomass was used to raise the RV survey biomass estimate of Arctic cod. The assumption is that the RV survey sampled each species equally poorly. This assumption is based on the difference between the biomass estimates obtained from the RV survey using Engels gear in 1992-1994, and using the Campelen gear in 1996-1997. Arctic cod biomass increased from an average of 4,015 t to 61,388 t while capelin biomass increased from 6,344 to 72,141 t. It is therefore assumed that the catchability of the two species is similar.

For capelin, the ratio of the acoustic biomass estimate for 2J3KLNO (6, 578,068 t) to the Campelen RV biomass estimate for 2J3KLNO (13, 730 t) was 479.1. This figure was applied to the mean biomass of Arctic cod in 1985-1987, giving a total biomass estimate of 1,350,713 t, 2.729 $t{\cdot}km^{-2}$.

Production:Biomass

There is little on which to base a production estimate of Arctic cod. Bradstreet *et al.* (1986) estimated mortality rates for Arctic cod in the Arctic. They constructed catch curves from numbers of Arctic cod at age found in the stomachs of predators, marine mammals and birds. They estimated a mean mortality of 0.409 yr^{-1} for 1 to 2 year olds and 0.38 yr^{-1} for 2 to 3 year olds. Lilly *et al.* (1994) found that most Arctic cod in 2J3KLNO were 1 and 2 years olds. On this basis, a mean of the two mortality estimates is taken to represent mortality of the population. Thus, assuming P/B = Z (Allen 1971), P/B is 0.395 yr^{-1} and annual production is 532,856 t.

Consumption:Biomass

In the absence of information on consumption by Arctic cod, it was assumed that the gross growth efficiency, the ratio between production and consumption, was 0.15. Thus consumption was calculated as 3,552,376 t and Q/B was 2.633 yr^{-1}.

Diet

The diet of Arctic cod (Appendix 2, Table 14) is a guess based on observations of a small number of fish caught off northern (Division 2G) and southern (Division 2J) Labrador in autumn 1978 (Lilly 1980) supplemented with unpublished observations of fish collected in Divisions 2J, 3K and 3L in autumn 1994. The first study revealed that small fish feed primarily on calanoid copepods and larger fish primarily on hyperiid amphipods. The second study revealed the same pattern but also indicated some predation by large Arctic cod on small capelin in Division 3L.

19 Large Pelagic Feeders (Bundy and Lilly)

Background

This group includes the sharks, such as the basking shark (*Cetorhinus maximus*), the spiny dogfish (*Squalus acanthias*), tunas such as the bluefin tuna (*Thunnus thynnus*), pollock (*Pollachius virens*), silver hake (*Merluccius bilinearis*), swordfish (*Xiphias gladius*) and Atlantic salmon (*Salmo salar*). These are large fish that feed pelagically. None are common in the study area, and pollock and silver hake are found in greater abundance on the Scotian Shelf. The sharks, tunas and salmon are highly migratory (Scott and Scott 1988) and spend only part of the year in the study area. There is very little information for this group and as such, it is poorly defined. For those species that have juveniles in the area, the juveniles are classified as small pelagics (see below).

Catch

Based on the total average catch within the study area of the species listed above given in NAFO Statistical Bulletins (Anon. 1987, 1989, 1990), and an average of 179 t caught as bycatch in the shrimp fishery (Kulka *pers. comm.*), the mean catch of the large pelagic feeders in 1985-1987 was calculated to be 2,693 t, or 0.006 $t \cdot km^{-2}$. Seventy-five percent of this catch is Atlantic salmon and silver hake.

Biomass

There is no biomass information for these species since they are mostly visitors to the area and are present for varying times. For this group, the model was used to estimate biomass by entering a default Ecotrophic efficiency value of 0.95 (Polovina 1984; Christensen and Pauly 1992).

Production:Biomass

For the most part, these species are fairly long-lived and lightly exploited in the study area. Their P/B ratio is thus likely to be low. Assuming the conventional natural morality rate of 0.2 yr^{-1} and assuming F=M, the P/B ratio was taken to be 0.4 yr^{-1}.

Consumption:Biomass

The are very few data on consumption:biomass for the large pelagic feeding species in the study area. Stillwell and Kohler (1985) give a range of 3.4 to 5.8 yr^{-1} for swordfish from Cape Hatteras to the Grand Banks. Pauly (1989) gives estimates of Q/B for several of the large pelagic feeding species in other areas (Table 10). Consumption in colder, northern waters is likely to be lower than these values. The maximum Q/B may be around 4 yr^{-1}.

Table 10. Q/B estimates from Pauly (1989).

Species	*Location*	*Q/B (yr^{-1})*
Basking Shark	North Sea	3.70
Spiny Dogfish	New England Coast	4.77
Pollock	Faeroe and Georges Bank	4.76
Silver Hake	Georges Bank	4.26
Swordfish	Cape Hatteras to Grand Banks	3.4-5.8[a]

[a] Stillwell and Kohler (1985)

Assuming a gross efficiency of 0.15 would give a Q/B of 2.667 yr^{-1}. The likely range of values is then 2.7 to 4 yr^{-1}. An intial Q/B of 3.333 yr^{-1} was used.

Diet

The diet of silver hake (Appendix 2, Table 15) is based on Vinogradov (1983) with modifications based on information in Vinogradov (1972) and Swan and Clay (1979) and assumptions regarding prey availability on Grand Bank.

The diet of pollock (Appendix 2, Table 15) is based on Steele (1963) with modifications to reflect assumptions regarding prey availability on Grand Bank.

A diet for large pelagic feeders was calculated as the average of the diets for the above two species. It was assumed that this diet, with its emphasis on pelagic fish and zooplankton, would be appropriate for the combination of other species within the group.

20. Piscivorous Small Pelagic Feeders (Winters, Bundy and Lilly)

Background

This group includes mackerel (*Scomber scombrus*), piscivorous myctophids and other mesopelagics and the short-finned squid (*Illex illecebrosus*). Mackerel and short-finned squid are highly migratory and spend only part of the year within the study area. The myctophids and other mesopelagics may remain in the area for the whole year. The group also includes piscivorous juveniles of the large pelagics.

Mackerel populations in the Northwest Atlantic form a stock complex which overwinters off the New England coast and migrates northwards in May and June after spawning in the Jersey Bight area and the southern Gulf of St. Lawrence (Moores *et al.* 1975). They sporadically enter Newfoundland waters in late June-early July and begin their southern overwintering migration in the late fall. Only mackerel and short-finned squid are fished commercially.

Catch

The mean catch of mackerel in NAFO Divisions 2J3KL for 1985-1987 was 7376 tons (Grégoire 1996). The short-finned squid catch statistics were taken from NAFO Statistical Bulletin (Anon. 1987, 1989, 1990), giving a total catch of 7405.7 t, or 0.015 $t \cdot km^{-2}$.

Biomass

Castonguay and Grégoire (1989) estimated that the mackerel population in the northwest Atlantic was exploited at an average level of about 4% during the 1985-87 period. If this level of exploitation pertains to the Newfoundland mackerel fishery, it implies an exploitable biomass of 184,411 tons for the period 1985-1987 period. This represents the average annual biomass and takes into account the period of residence in the area (since catch only occurs during periods when mackerel are present).

The biomass of the other species is not known. The biomass of short-finned squid is likely to have been low in 1985-1987 because catches were very small. It is assumed that the combined biomass of short-finned squid and myctophids may range from 10,000 to 30,000 t, giving a biomass range of 204,411 - 244,411, or 0.413 - 0.494 $t \cdot km^{-2}$. A midrange value of 224,411 t, 0.453 $t \cdot km^{-2}$ was used as an initial input biomass.

Production:Biomass

A P/B ratio of 0.29 yr^{-1} was calculated for mackerel in the North Sea from MSVPA data (Christensen 1995). This value is similar to the value of 0.24 yr^{-1} produced by assuming that production is equivalent to natural mortality times the biomass plus the catch (or P/B=Z). These values are taken to represent the P/B of the small pelagic feeders, producing a total annual production of between 54,169 and 64,769 t for 1985-1987 when the biomass was 224,411 t. A mid-value of 0.265 was used as the initial P/B value.

Consumption:Biomass

There are no consumption figures for the small pelagic feeders in the study area. Pauly (1989) gives a Q/B value of 4.4 yr^{-1} for mackerel on Georges Bank. However, assuming a GE of 0.15 would result in a Q/B of 1.767. These two values are quite different. In the absence of further information the default assumption of GE=0.15 is used as an initial input value, but it is noted that Q/B may be as high as 4.4 yr^{-1}. A Q/B of 1.767 results in a total annual consumption of 396,459 t by the piscivorous small pelagic feeders.

Diet

The derivation of the diet of the piscivorous small pelagics is given in Appendix 2, Table 16. The diet of mackerel is taken from Moores *et al.* (1975). The diet of piscivorous myctophids and other mesopleagics) is a guess, based on diet information in Podrazhanskaya (1993) and Gartner *et al.* (1997). The diet of short-finned squid was based on sampling in the inshore of eastern Newfoundland (Dawe 1988; Dawe *et al.* 1997). The time and location of samples of short-finned squid probably yields an underrepresentation of the importance of capelin and crustacean zooplankters, so both groups are adjusted upward and the values for Atlantic cod and sand lance are adjusted downward.

The diet for piscivorous small pelagics was calculated as the weighted average of the diets for mackerel, mesopelagics and squid.

21. Planktivorous Small Pelagic Feeders (Winters, Bundy and Lilly)

Background

This group includes herring (*Clupea harengus harengus*), planktivorous myctophids and other mesopelagics, and the Atlantic saury (*Scomberesox saurus*). Also included are Arctic squid (*Gonatus* sp.) and the planktivorous juveniles of the large pelagics. Herring, myctophids, other mesopelagics and Arctic squid remain in the area for the whole year. The Atlantic saury is highly migratory and spends only part of the year within the study area.

Only herring are commercially fished. Three major stocks are recognized within the study area, viz. White Bay-Notre Dame Bay, Bonavista Bay-Trinity Bay, and Conception Bay-Southern Shore (Wheeler and Winters 1984).

Catch

The average catch of herring in the study area during the 1985-1987 period was 9,000 t (Wheeler *et al.* 1989). The other catch statistics were taken from NAFO Statistical Bulletins (Anon. 1987, 1989, 1990) giving a total catch of 9322 t, or 0.019 t·km^{-2}.

Biomass

The average biomass of herring during the period 1985-1987 for the White Bay to Trinity Bay area is 212,000 tons (Wheeler *et al.* 1989). There is no estimate of biomass available for the Conception Bay-Southern Shore stock for this period, but historically this has been a small stock amounting to no more than 10% of the biomass of the northern stock. Thus, the total herring biomass is approximately 235,000 tons.

The biomass of the other species is not known. The biomass of the Atlantic saury is likely to have been low in these years because catches were very small. However, the biomass of the planktivorous myctophids and other mesopelagics may have been as high or higher than herring. In the absence of further information, a biomass range is used, from 352,500 - 587,500 t , or 0.712 - 1.187 t·km^{-2}. This allows for up to 60% of the biomass to be composed of myctophids, mesopelagics and Arctic squid. A mid range value of 470,000 t, 0.949 t·km^{-2}, was used as the initial input biomass.

Production:Biomass

A P/B value of 0.24 yr^{-1} is produced by assuming that production is equivalent to natural mortality times the biomass plus the catch. This is taken to represent the P/B of the planktivorous small pelagic feeders, producing a total annual production of 112,800 t for 1985-1987.

Consumption:Biomass

There are no consumption figures for the small pelagic feeders in the study area. Pauly (1989) gives a Q/B value of 4.59 yr^{-1} for herring on Georges Bank. However, assuming a GE of 0.15 would result in a Q/B of 1.60. These two values are quite different. In the absence of further information, the default assumption of GE=0.15 is used as an initial input value, but it is noted that Q/B may be as high as 4.59 yr^{-1}. A Q/B of 1.6 results in a total annual consumption of 752,000 t by the planktivorous small pelagic feeders.

Diet

The derivation of the planktivorous small pelagics diet is given in Appendix 2, Table 17. The diet of herring is taken from Messieh *et al.* (1979), who studied fish from the Gulf of St. Lawrence and adjacent waters. The diet of myctophids and other mesopleagics is a guess, based on diet information in Podrazhanskaya (1993) and Gartner *et al.* (1997) and the assumption that myctophids and other planktivores comprise most of the biomass.

The diet for small pelagics was calculated as a weighted average of the diets for herring, myctophids and mesopelagics, and Arctic squid.

22. Shrimp (Parsons and Bundy)

Background

Several species of penaeid and caridean shrimp occur within the study area. Northern shrimp (*Pandalus borealis*) dominates the biomass and is fished commercially. It is taken as the representative species for this group. The fishery during 1985-1987 occurred only in the northern area, that is 2J3K. There was virtually no fishery in 2J3K in 1985, some in northern 2J in 1986 and a little more throughout 2J with a small bit in 3K in 1987. Northern shrimp off northeastern Newfoundland and southern Labrador generally prefer muddy substratum at depths greater than 200 m where water temperatures are in the range of 2-4 °C. Thus, the potential habitat for the species is extensive throughout the study area. Fishery and survey data suggest that animals occurring in the northern part are highly concentrated during winter and spring, but are more widely dispersed in late summer and early fall.

Catch

The study period captures the initial stages of a rapid expansion of the fishery. After an increase in catches from the late 1970s to early 1980s, the fishery in Division 2J declined to a minimum in 1985 when only 2 tons were reported. This increased to 1328 t in 1986 and 3263 t in 1987, giving an average annual catch of 1531 tons (DFO, pers. comm). In addition to the directed catch, there was also a by-catch of 210.2 t of other shrimp in the shrimp fishery during 1985 to 1987 (D. Kulka, *pers. comm.*). This makes the total catch 1,741.2 t, or 0.004 t·km^{-2}.

Biomass

No biomass estimates for the whole study area are available for this period. Surveys in the 1980s were conducted in depressions of the northeast Newfoundland-Labrador Shelf where the fishery occurred and/or where bottom trawling was possible. Three areas surveyed in 1985 produced an estimate for northern shrimp of around 10,000 t (Parsons and Veitch, 1991). However, this is a very minimal estimate given the unquantified efficiency of the survey gear, the vertical distribution of the shrimp out of range of the gear, and the unknown biomass that exists in untrawlable and other areas. For example, Lilly *et al.* (1998) described a broader distribution of northern shrimp inferred from both commercial fishery data and the stomach contents of Atlantic cod. They also showed that the distribution of northern shrimp extends south into 3L and the density of the striped pink shrimp (*P. montagui*) may be greater in 3L than in 2J3K.

Given the uncertainties in the data, it is necessary to assume that the biomass is greater than 10,000 t. Recent biomass (1996-97) is estimated at roughly 400,000 t and the standardized catch rate has increased by 3.75 from 1988 to 1997 (Parsons and Veitch, 1998). Assuming the CPUE reflects the general trend in abundance, it is estimated that the mean biomass of northern shrimp from 1985-1987 was about 100,000 t. This extrapolation is for northern shrimp alone, but it is assumed the 100,000 t, 0.202 t·km^{-2} is representative of the total shrimp biomass.

Production:Biomass

Three are no production or mortality estimates from shrimp in the study area. Hopkins and Nilsen (1990) estimated a total mortality of 1.83 from survival curves and length converted catch curves for northern shrimp in northern Norway. Hopkins (1988) estimated a P/B ratio of 1.7, using VBGF parameters and mortality (estimated by the length converted catch curve) amongst other input parameters. However, on the Newfoundland-Labrador shelf (Division 3K) northern shrimp grows to a greater size and older age and has a slower growth rate than in northern Norway (Parsons *et al.* 1986; Hopkins and Nilsen 1990). This indicates that the P/B ratio for the Newfoundland-Labrador Shelf northern shrimp should be less than either of the above estimates. A range of P/B values, from 1.2 to 1.7, is suggested and a value of 1.45 is used as an initial P/B.

Consumption:Biomass

In the absence of information on the food consumption rate by shrimp, consumption was estimated by assuming a gross growth efficiency of 0.15. This produces a Q/B ratio of 9.667 yr^{-1} when P/B=1.45 yr^{-1} and a total annual consumption of 966,700 t.

Diet

Feeding occurs in the benthic and the pelagic environments. Previously thought to be primarily a benthic feeder (see Shumway et al 1985 for a review), northern shrimp is now known to feed extensively in the pelagic zone (e.g. Hopkins *et al.*, 1993; Wienberg, 1981). The benthic diet is comprised mainly of detritus, phytoplankton and benthic invertebrates; the pelagic diet is comprised of detritus, small zooplankton and large zooplankton (DFO, unpublished data). The benthic and pelagic diets were combined assuming that 30% of the total diet is benthic and 70% is pelagic. The resultant diet is given in Table 2b.

23. Large Crustaceans (Dawe, Ennis and Bundy)

Background

The large crustacean group is comprised of the American lobster (*Homarus americanus*) and the snow crab or queen crab (*Chionoecetes opilio*), both of which were exploited in the mid-1980s, and various non-commercial species such as toad crabs (*Hyas* spp).

Catch

The 1985 - 1987 average catch of American lobster and snow crab was 701 t and 7101 t respectively (NAFO Statistical Bulletins 1986, 1987, 1990). The total large crustacean catch was therefore 7802 t, 0.016 $t{\cdot}km^{-2}$.

Biomass

The biomass of the lobster was first approximated by dividing the catch by the exploitation rate (Ennis *et al.* 1982, Ennis *et al.* 1989). The estimate is for the exploited part of the stock and does not include either ovigerous females of commercial size or undersized lobsters, ie., pre-recruits. The biomass estimate was first increased to allow for commercial sized ovigerous females, using size-structure data from commercial sampling, and based on their relative abundance and size composition in research samples. Lobsters smaller than the minimum legal size of 81 mm carapace length (CL) were estimated by back calculating from the number in the 81-90 mm CL length class, assuming a natural mortality of 0.1. The process of back-calculation was repeated for the 61-70 mm, 51-60 mm, 41-50 mm and 31-40 mm length groups. Biomass of the 31-40 mm groups decreased to about 10% of the ≥ 81 mm groups. Biomass of the ≤ 31-40 mm length group was assumed to be 10% of the ≥ 81 mm group. This gave the mean annual biomass for 1985 - 1987 of 2217 t.

Biomass estimates for the snow crab were made using fall bottom-trawl survey estimates for 1995-1997 (Dawe *et al.* 1997, in prep.) and the relationship between these biomass estimates and commercial CPUE (kg/trap haul) (Taylor and O'Keefe, in prep.) from the trap fishery in each of those years. From this relationship it is possible to estimate the catchability coefficient, q , which in this case represents the proportion of the resource removed by one trap haul (q=CPUE/Biomass). Biomass is a conservative estimate of the initial exploitable biomass calculated by summing the catch and the residual fall (minimum trawlable) biomass. It is considered to be conservative because the catchability of the survey trawl is assumed to equal 1. Assuming q to be constant over time, the 1997 estimates of q for each NAFO Division were applied to commercial CPUE data for each of the years 1985-1987 to generate biomass estimates (Biomass=CPUE/q). These biomass estimates were adjusted upward to account for sublegal-sized males and females. This adjustment factor was based on the estimated maximum contribution of non-commercial snow crabs to the 1995-1997 total biomass estimates (55% in 1995) (Dawe *et al.* 1997, *in prep.*). Use of the maximum is justified in that biomass of this component must have been high during 1985-1987, because CPUE began to increase regularly after this period (Taylor and O'Keefe *in prep.*), indicating increasing recruitment. This too may be conservative if catchability of the survey trawl is lower for smaller crabs. The resultant total biomass of 86,345 t is considered to be a minimum estimate.

The biomass of the other crab species was calculated from the fall bottom-trawl survey estimates for 1995-1997 (Joe Drew, DFO, unpublished data, *pers. comm.*). It is assumed that since these species were not exploited until the 1990s, these biomass estimates represent a minimum unexploited biomass. The mean minimum trawlable biomass for 1995 to 1997 was 2,901 t.

The total large crustacean biomass estimated for 1985-1987 was 91,462 t. For the model area this gives an estimate of 0.185 t·km^{-2}.

Production:Biomass

In the absence of mortality estimates for either the lobster or crabs, the production biomass ratio was estimated from catch and biomass data and an assumed natural mortality of 0.1 to 0.3. This produces a mean P/B of 0.182 to 0.382 yr^{-1}, or total production of 16,668 to 34,961 t per year. The midpoint of this range, 0.282 yr^{-1}, was used as the initial input value for P/B.

Consumption:Biomass

There were no consumption data available for the snow crab so it was assumed that the consumption rates of lobsters are representative of the crabs. The consumption to biomass ratio for lobsters was calculated from data in Reddin (1973). Reddin studied the consumption of lobsters caught at various parts of the coast around Newfoundland. He maintained them at ambient seawater temperature in the laboratory for one year, and fed them a diet of either 100% rock crab (*Cancer irroratus*) or 100% sea urchin (*Strongylocentrotus droebachiensis*). The total annual calorific consumption of *C. irroratus* was 2663 cal/g lobster and of *S. droebachiensis* was 1425 cal/g lobster. Reddin estimated the calorific content of *C. irroratus* as 4211 cal/g dry wt and of *S. droebachiensis* as 3448 cal/g dry wt. Converting this to cal/g wet wt (assuming 10 g wet wt = 1 g dry weight), the weight of prey consumed was estimated as the calorific consumption by lobster divided by the calorific content of prey. This produced an annual consumption rate of 6.32 yr^{-1} when the lobsters were fed 100% *C. irroratus* and 4.42 yr^{-1} when the lobsters were fed 100% *S. droebachiensis*. Based on the diet composition given below, the weighted mean of these two estimated is 5.85 yr^{-1}, giving a total annual consumption of 533,888 t.

Diet

The diet data shown in Table 2b is based on the weighted mean of the lobster and snow crab diets. The lobster diet data from Bonavista Bay in Ennis (1973) were used and adapted slightly.

Diet data from western Newfoundland (Wieczorek and Hooper 1995) and Conception Bay in eastern Newfoundland (Miller and O'Keefe 1981) were used as a basis for the diet of the snow crab. Diet data in Lovrich and Sainte-Marie (1997) were also used for comparative purposes. The data were presented in terms of percentage occurrence whereas what is required here is percentage wt of stomach contents. On the basis of similarity in frequency occurrence in Wieczorek and Hooper (1995) and Miller and O'Keefe (1981), the prey items were allocated a percentage weight value.

24 - 27. The Benthic Invertebrates (Bundy and Gilkinson)

Background

The benthic invertebrates are treated as four groups: Echinoderms, Molluscs, Polychaetes and Other Benthic Invertebrates (OBI). The other benthic invertebrates include miscellaneous crustaceans, nematodes, and other meiofauna. These groupings reflect the major taxa observed on the Grand Bank (Nesis 1965; Hutcheson *et al.* 1981). The most recent comprehensive source of information on the benthos is a study carried out in 1980 under the auspices of the Mobil Oil company on the Grand Banks (Hutcheson *et al.* 1981). Five stations were sampled from May to November 1980. Barrie (1979) and Barrie *et al.* (1980) conducted a coastal study of marine benthic communities off the Labrador coast in 1977 and 1979. Additional quantitative information on marine benthic communities collected in conjunction with a three year trawling impact experiment on the Grand Bank (Prena *et al.* 1996; Gordon *et al.* 1997) is not yet available. The best source of published information is the Mobil study on the Grand Banks. The Labrador coast studies generally corroborate the results of this study. However, it should be stressed that benthic data are poor, and several assumptions are made below in order to obtain model parameter estimates.

Large scale differences in the distribution of benthic species are correlated with water mass type (Nesis 1965). Depth integrates the variables of water column productivity and sediment textural type. It is now clear that infauna-sediment relationships are much more variable than traditionally purported and the distributions of this group cannot be explained on the basis of sediment grain size alone (Snelgrove and Butman 1994). Schneider *et al.* (1987) demonstrated that mobility of megafauna determines the range over which they are associated with substrate variability. For the purposes of this model, however, the scale of interest is the southern Labrador shelf, Northeast Newfound Shelf and Grand Bank. Therefore little attention is paid to small scale changes in species distribution. High productivity on Grand Bank is linked to a shallow water depth and mixing of waters from the Labrador current, shelf waters, and southern waters. However, high productivity may be also be due to cold water temperatures which suppress water column microbial metabolism, resulting in more organic matter made available to consumers (Pomeroy and Deibel 1986).

The benthic groups are all common on Grand Bank (Hutcheson *et al.* 1981). Polychaete worms are numerically the most dominant group, and in particular *Exogene hebes*, which had a mean numerical density of 220 m^{-2}. Echinoderms and molluscs contribute most to the benthic biomass. The sand dollar, *Echinarachnius parma*, is a consistent feature of sand assemblages with a mean numerical density of 25 m^{-2}. The bivalve mollusc, *Mesodesma* *deauratum*, occurs at very high densities, up to 22 kg·m^{-2}, on the south east portion of the bank. However, this is very localised, and other mollusc species, such as the propeller clam (*Cyrtodaria siliqua*), which has maximum mean biomass of around 500 g·m^{-2} (= 500 t·km^{-2}) on sandy bottoms (K. Gilkinson, unpublished data - this figure was derived from a hydraulic grab that penetrates deeper into the substrate than the van Veen grab - see below), are more common on Grand Bank. Hutcheson *et al.* (1981) reported that there are no strong seasonal changes in dominant species at the five stations.

The surficial sediments on Grand Bank consist primarily of sands and gravels of various coarseness grades. Sands below 110 m water depth have few associated gravels while those above are interspersed with gravels, originating primarily from Pleistocene glacial deposits. At shallower depths, surficial sediments have been re-worked by a combination of a Holocene marine transgression and modern hydrodynamic processes (Barrie *et al.* 1984; Barrie and Collins 1989). In the Labrador study (Barrie *et al.* 1980) the dominant substrate at all sites was fine sand.

Catch

Polychaetes, echinoderms and OBI were not commercially caught in 1985-1987. The only benthic invertebrate species (as classified in this Ecopath group) that was commercially landed during 1985 - 1987 was a mollusc, the giant scallop (*Placopecten magellanicus*), with average annual landings of 121 t, or 0.0003 t·km^{-2} (Anon 1987, 1989, 1990).

Biomass

The estimate of mean biomass for each of the four benthic groups was estimated from data from the Mobil study. Hutcheson *et al.* (1981) sampled five stations on the Grand Banks, including the Hibernia Station, which consisted of 10 stations in the area, and station 24 which was on St. Pierre Bank in NAFO Subdivision 3Ps. The locations of the stations were chosen to reflect the water mass qualities described by Nesis (1965). Station 3 was at the north edge of the bank, station 33 in the middle of the bank in a region of mixed waters, and station 48 was near the edge of the bank on the Southeast Shoal, a region of high productivity. Samples were taken with a 0.1 m^2 van Veen grab. Samples were also taken with an epibenthic sled, which, because of operation difficulties, were qualitative. However, they supported the results of the grab samples.

The results demonstrated that benthic communities at station 3, on the northern edge of the Grand Bank, had a strong arctic component and were different from the species at the other stations. It was assumed that the benthic composition at this station was representative of the benthic composition of the Labrador Shelf area, that is, of 2J3K. For 3LNO, roughly the Grand Bank, a weighted average of the mean weights at each station was calculated for each benthic group, based on Figure 3 and Figure 8 in Nesis (1965). Figure 3 gives the distribution of benthos biomass by weight groups (<100g, 100-1000g, >1000g) and Figure 8 is a map of the distribution of water types in the bottom layers. The stations from the Mobil study were mapped onto these maps and given a representative coverage of the Grand Bank (or 3LNO) based on biomass distribution and water mass type. The area covered by each station was estimated as 55% for station 3, 44% for station 33, 2.5% for Hibernia and 2.5% for station 48.

The biomass of the molluscs is very large, especially on the Southeast Shoal, but also in 2J3KL. However, only part of this biomass, the soft body tissue, is transferred through the food web. This is confirmed by observations of huge shells beds on the ocean floor (Hutcheson *et al.* 1981). In order to reduce the biomass and account for soft body tissue only, the ratio of the body weight to whole weight of the locally abundant mollusc ***Mesodesma deauratum*** was estimated. The mean ratio between blotted wet weight of tissue weight to whole weight for animals with a shell length between 30 and 35 mm was 0.166 with a standard deviation of 0.023, n=10 (Gilkinson, unpubl.).

The estimate of benthic biomass for 3LNO is 230.6 $t \cdot km^{-2}$ (Table 11). The mean biomass estimates for 2J3KLNO are the weighted mean of the three areas, and the total mean benthic biomass for 2J3KLNO is 127.7 $t \cdot km^{-2}$.

Table 11. Estimates of mean benthic biomass in 2J3KLNO.

	2J or 3K Biomass ($t \cdot km^{-2}$)	*3LNO Biomass ($t \cdot km^{-2}$)*	*2J3KLNO Biomass ($t \cdot km^{-2}$)*
Echinoderms	70.6	144.8	112.3
Molluscs	16.4	62.2	42.1
Polychaetes	8.8	11.9	10.5
Other Benthic Invertebrates	2.7	11.8	7.8
Total Benthos Biomass	98.5	230.6	127.7

Hutcheson *et al.* (1981) estimated a total benthic biomass on the Grand Banks of 480.7 $t \cdot km^{-2}$. The estimate of 230.7 $t \cdot km^{-2}$ is half this. However, if the mollusc biomass is not corrected for shell weight, as in Hutcheson *et al.* (1981), then the estimates are similar (544.2 $t \cdot km^{-2}$). The Hutcheson *et al.* estimate of benthic biomass was not used because they omitted certain data from their estimate and it was not clear how they combined the stations into an overall mean. Nesis (1965) estimated a total benthic biomass of 154 $t \cdot km^{-2}$ for the Grand Bank and the Labrador Shelf. The estimate here is comparable.

The mean biomass estimate in Table 11 may be an underestimate of the total benthic biomass. In particular, the molluscs may be undersampled. The 0.1m^2 van Veen Grab does not deeply penetrate the compacted sands on the northeast Grand Bank and therefore misses some large deep burrowing bivalves (Gilkinson, unpubl.; Prena *et al.* 1996). However, these are the only currently available published biomass estimates for Grand Bank.

Production:Biomass

There are some empirical production data for the mollusc group on Grand Bank. For the other benthic groups, all the estimates are taken from literature sources. The resultant estimates are shown in Table 12.

Echinoderms

Robertson (1979) estimated an annual P/B of 0.65 yr^{-1} and Jarre-Teichmann and Guenette (1996) used an estimate of 0.6 yr^{-1} for the southern BC shelf. In the absence of other information, the lower of the two estimates, 0.6 yr^{-1}, is used here. This translates into an annual production of 67.4 t·km^{-2}·yr^{-1} of echinoderms.

Molluscs

Hutcheson *et al.* (1981) estimated the P/B ratio of the bivalve *Mesodesma deauratum* from the Southeast Shoal area of Grand Bank as 0.57 yr^{-1} for small individuals and 0.11 yr^{-1} for large ones. Robertson (1979) estimated a P/B of 0.76 yr^{-1} for molluscs and Jarre-Teichmann and Guenette (1996), based on their interpretation of Brey's (1995) database on macrobenthic productivity, estimated a mean P/B of 0.7 yr^{-1} for molluscs on the southern shelf of British Columbia. Unfortunately, Hutcheson *et al.* (1981) do not specify how large a large *M. deauratum* is, or what proportion of the population is large. To allow for the higher estimates originating in warmer waters (and therefore having a greater productivity), the lower estimate of 0.57 yr^{-1} is used, producing 24 t·km^{-2}·yr^{-1} of molluscs.

Polychaetes

Estimates of polychaete P/B ratios range between 2 and 3 yr^{-1} (Mills and Fournier 1979; Collie 1987; Jarre-Teichmann and Guenette 1996). Curtis (1977) estimated a lower value of 1.4 yr^{-1} for polychaetes off West Greenland. To allow for the higher estimates originating in warmer waters (and therefore having a greater productivity), the lower bound of 2 yr^{-1}, that is a production of 21 t·km^{-2}·yr^{-1}, is used.

Other Benthic Invertebrates (OBI)

Little is know about production of the OBI. The amphipods are assumed to represent this group. P/B estimates for amphipods include 2.5-4.4 yr^{-1} (on Georges Bank, NE USA) (Collie 1985), 2.5 yr^{-1} (Mills and Fournier 1979) and 2.5 yr^{-1} (Jarre-Teichmann and Guenette 1996). The common estimate of 2.5 yr^{-1} is used, producing 19.521 t·km^{-2}·yr^{-1} of other benthic crustaceans.

The total benthic production is 132 t·km^{-2}·yr^{-1}. The greatest production is by the echinoderms while the other 3 groups have a similar annual production. This compares to a total mean macrobenthic production of between 12 and 533 t·km^{-2}·yr^{-1} on Browns Bank, Nova Scotia (Wildish *et al.* 1989) and 360 t·km^{-2}·yr^{-1} on Georges Bank (Sissenwine *et al.* 1984).

Consumption:Biomass

The Q/B ratio is estimated from the gross efficiency (GE) for all four benthic groups. Jarre-Teichmann and Guenette (1996) estimated GE for benthic groups on the southern BC Shelf. Using their values, the molluscs, polychaetes and echinoderms, all detritus feeders (see below), have a GE of 9%, or 0.09. The other benthic invertebrates have a GE of 20%. These GE values equate to the Q/B and consumption rates shown in Table 12.

Table 12. Production and consumption estimates for the four benthic groups.

Benthic Group	P/B (yr^{-1})	P (t·km^{-2}·yr^{-1})	GE	Q/B (yr^{-1})	Q (t·km^{-2}·yr^{-1})
Echinoderms	0.6	67.4	0.09	6.7	748.5
Molluscs	0.6	24.0	0.09	6.3	266.9
Polychaetes	2.0	21.0	0.09	22.2	233.8
Other Benthic Invertebrates	2.5	19.5	0.20	12.5	97.3

The greatest consumption is by echinoderms, followed by molluscs and polychaetes.

Diet

Much of the diet information on these benthic groups originates in the work of Nesis (1965) and Hutcheson *et al.* (1981). Here, the diets are described in terms of the groupings used in the Ecopath model. Essentially, they are all described as benthic feeders. It should be noted however, that these data are simplified. It was not possible to review all the available information on congeneric and conspecifics in the literature.

Echinoderms

The echinoderms are basically detritivores. The sand dollar *Echinarchnius parma*, the most common echinoderm in the study area, is a surface detritivore (Hutcheson *et al.* 1981; Mooi and Telford 1982). The sea urchin *Stronglyocentrotus pallidus* eats animal remains and detritus (Gilkinson *et al.* 1988) and the brittle star *Ophiura robusta* is a detritivore (Nesis 1965). The diet of this group then is 100% detritus.

Molluscs

Among the bivalves, *M. deauratum* is a suspension feeder, *Macoma calcarea* is a deposit feeder, and *Liocyma fluctuosa* is a suspension or detrital feeder (Hutcheson *et al.* 1981). Suspension feeders feed on organic detrital matter which is re-suspended in the water immediately above the sediment surface. Deposit feeders can be considered detrital feeders. Thus, the molluscs can be said to be detrital feeders of various forms and the diet of the mollusc group is 100% detritus.

Polychaetes

The polychaetes are detritivores and have a diet of 100% detritus (Nesis 1965; Fauchuld and Jumars 1979).

Other Benthic Invertebrates (OBI)

Gammarid amphipods, the representative taxon for this group, feed on organic detritus (Nesis 1965; Hutcheson *et al.* 1981). The Cumacea and Isopoda are also detritivores (Hutcheson *et al.* 1981).

28 - 29. Zooplankton (Bundy and Deibel)

Background

Zooplankton are an important link in marine food webs. They transfer organic carbon from phytoplankton to fish, marine mammals and birds higher in the food chain, they are a food source for a broad spectrum of species and they contribute faecal matter and dead zooplankton to the benthic communities. The most recent comprehensive source of information on the zooplankton in the Newfoundland region is a study carried out on the Grand Banks in 1980 under the auspices of the Mobil Oil company (Strong 1981). Strong (1981) sampled the Grand Banks on fifteen oceanographic cruises from March 1980 to February 1981, using a neuston net of 333 μm to sample surface dwelling zooplankton, a bongo sampler equipped with twinned 333 μm mesh nets, and a ring net with mesh size of 80 μm, designed to capture microzooplankton. Over eighty-six species of zooplankton were caught, and arctic and boreal species numerically dominated the samples. The copepod *Calanus finmarchius* dominated the 333 μm bongo and neuston samples. Two other *Calanus* species, *C. glacialis* and *C. hyberboreus*, characteristic of cold arctic waters, were also found in smaller numbers beyond the 200 m isobath. Other species included tunicates (*Oikopleura spp.*), chaetognaths (*Parasagitta elegans*), amphipods (*Parathemisto gaudichaudii*) and molluscs (*Limacina spp.*). The cyclopoid copepod *Oithona similis* dominated the ring net samples, and were most abundant within the 200 m isobath. Few euphausiids were caught and apparently they play a minor role on the Grand Banks (Strong 1981), although this is probably an artifact due to sampling technique. Gelatinous zooplankton, such as the tunicates, are generally underestimated by sampling gear, but are considered to have a very important role in marine ecosystems (Alldredge 1984; Deibel 1988; Knoechel and Steel-Flynn 1989; Madin and Deibel 1998).

The zooplankton are treated here as two groups. The large zooplankton group are greater than 5 mm in length and include euphausiids, chaetognaths, hyperiid amphipods, Cnidarians and Ctenophores (jellyfish), mysids, tunicates >5 mm and icthyoplankton. This group feeds herbivorously (some euphausiid species), omnivorously (most euphuasiids, hyperiid amphipods, mysiids and large tunicates) and carnivorously (chaetognaths and jellyfish). The small zooplankton includes zooplankton less than or equal to 5 mm in length. Copepods, mainly *Calanus finmarchicus* and *Oithona similis*, are the most numerous small plankton. Other small plankton include tunicates < 5 mm and meroplankton. *C. finmarchicus* and *O. similis* are omnivorous.

Catch

None.

Biomass

Strong (1981) estimated an mean annual standing crop of zooplankton from the bongo net of 4.38 $kcal \cdot m^{-2}$, which is equivalent to 7.3 $t \cdot km^{-2}$, using the conversion factor 0.6:1 for zooplankton, estimated by Mills and Fournier (1979). This figure is for zooplankton within the 200 m isobath. Incorporating the microzooplankton from the ring net sample with an approximate calculation, Strong (1981) estimated the total zooplankton biomass to be 35.8 $t \cdot km^{-2}$.

This estimate however, does not include a fair representation of the gelatinous zooplankton which are damaged in the net, the jellyfish that are too large, and larval crustaceans (meroplankton) and chaetognaths that are too fast (Strong 1981). In addition, it is only for the Grand Banks.

An alternative method to estimate biomass was used here. Since 1994, a broad-scale survey has been carried out over 2J3KLNO in late summer by DFO using two ships (Anderson and Dalley 1997). The survey captures zooplankton from size 0.4-10 mm and nekton sized 10-200 mm. The surveys use a 333 μm bongo net and an IYGPT trawl (International Young Gadoids Pelagic Trawl). Although the survey is aimed at young-of-the-year fish and older capelin, it also represents a broad-scale measure of the zooplankton communities in the late summer. Zooplankton biomass, sampled by the bongos, was highest over the Northeast Newfoundland Shelf (Anderson and Dalley 1997). Indeed, Anderson and Dalley (1997) suggest that pelagic productivity, including production by nekton, may be greater over the Northeast Newfoundland Shelf than on Grand Bank. For this reason, and the better sampling technology, zooplankton biomass is estimated from these data in preference to the earlier data of Strong (1981), which only covered Grand Bank out to the 200 m isobath.

Large Zooplankton

The biomass of the large zooplankton was estimated from the IYGPT trawl data. These data are split into three categories: fish, jellyfish and "other" which are basically euphausiids and amphipods. It is assumed that the jellyfish and "other" categories are representative of the large zooplankton biomass. Unfortunately, there are data only for 1996 and 1997 for these groups and it is assumed that they are representative of the period 1985-1987. The mean biomass of the jellyfish was 1.6 and 0.8 $g \cdot m^{-2}$ (= $t \cdot km^{-2}$) in 1996 and 1997, and for the "others" was 0.6 $g \cdot m^{-2}$ in both years (data supplied by Denise Davis, DFO).

Koslow *et al.* (1997) estimate that the catchability of the IYGPT trawl is 0.14, meaning that the trawl catches 14% of the animals that it encounters. This catchability factor was used to raise the biomass estimates to 11.14 and 5.79 $t \cdot km^{-2}$ for jellyfish in 1996 and 1997 and 4.11 and 4.61 $t \cdot km^{-2}$ for the "others". A mean of the 1996 and 1997 values was taken for both groups and the figures adjusted for seasonality as described above. This gives a total mean biomass estimate of 18.343 $t \cdot km^{-2}$ for the large zooplankton.

Small Zooplankton

The biomass of the small zooplankton was estimated from bongo data from 1994-1997. The high contribution of the microzooplankton to the total zooplankton biomass estimated by Strong (1981) is ignored since they are not sampled by the bongo net. Zooplankton samples have a high variance and it is assumed that this variance will allow for the microzooplankton. Thus, the bongo net sample is assumed to represent the small zooplankton.

During the period 1994-1997, small zooplankton have increased inshore, in the north over the Northeast Newfoundland Shelf and in the south over Grand Bank. The mean biomass for each year is 11.8, 16.3, 17.3 and 30 $t \cdot km^{-2}$ (data supplied by Denise Davis, DFO). These figures compare to the 7.3 $t \cdot km^{-2}$ estimated by Strong (1981) for the Grand Banks.

It is assumed, for want of better information, that the catchability of the bongos is 1. However, the biomass figures above are the estimates for late summer, after the spring bloom (Strong 1981). In order to account for seasonality and thus obtain a representative annual biomass estimate, the late summer figures were adjusted for seasonality using the ratio of the monthly displacement volumes of zooplankton from the bongo net samples to the late summer value (Strong 1981, Table 5-2). The resultant estimates are given in Table 13.

Table 13. Small zooplankton biomass estimates for 2J3KNLO (t·km^{-2}).

	1994	*1995*	*1996*	*1997*
Small Zooplankton Biomass	11.8	16.3	17.3	30.0
Seasonally adjusted Biomass	16.9	23.4	24.8	42.9

The average of the 1994-1996 biomass estimates, 21.7 t·km^{-2}, is used to represent the small zooplankton biomass for the period 1985-1987. The year 1997 is not included since it is clearly much higher than the other years, and there is no reason to assume that there was particularly high small zooplankton biomass in 1985-1987. The biomass estimate of 21.7 t·km^{-2} may be compared to a copepod biomass of 25.1 g·m^{-2} (= t·km^{-2}) estimated from production and P/B estimates from the Emerald Bank (Scotian Shelf) in 1979-1980 by McClaren *et al.* (1989).

Production:Biomass

Large Zooplankton

Mauchline (1985) estimated P/B ratios of euphausiid species in the Rockall Trough, in the Atlantic west of Ireland. Three of the species are known to occur in 2J3KLNO; *Thysanopoda acutifrons*, *Meganyctiphanes norvegica* and *Thysanoessa longicaudata*. The P/B ratios are 2.3, 1.6 and 6.4 yr^{-1} respectively. In the absence of other information for the large zooplankton, an average value of 3.433 yr^{-1} is taken as the P/B ratio.

Small Zooplankton

McClaren *et al.* (1989) estimated annual P/B ratios for a range of copepod species on the Scotian Shelf, which is similar to the southern Grand Bank. It is assumed that *C. finmarchius* is the representative species for this group. It has a P/B ratio of 8.4 yr^{-1}. Sakshaug (1997), however, estimated a P/B of 4.0 for copepods in the Barents Sea, a system similar to the northern part of the study area. It should be noted that the cyclopoid copepod *Oithona similis*, which also belongs to the small zooplankton, has a much higher P/B ratio of 23 yr^{-1} on the Scotian Shelf and the P/B ratios for tunicates ≤ 5 mm are not known. A range of P/B ratios, with a minimum of 4.0 yr^{-1} and maximum of 8.4 yr^{-1}, is used to represent the small zooplankton. A mid-range value of 6.2 yr^{-1} was used as the initial input P/B ratio.

Consumption:Biomass

Large Zooplankton

There is some information on Q/B values for the large zooplankton. Sameoto (1976) examined the energy budgets of 3 euphausiid species in the Gulf of St. Lawrence. These species also occur in 2J3KLNO. Using his figures, a Q/B of 5 yr^{-1} was estimated for *Meganyctiphanes norvegica*, 16 yr^{-1} for *Thysanoessa inermis* and 37 yr^{-1} for *Thysanoessa raschii*. Heyraud (1979) collected *M. norvegica* from the waters of Nice, France and kept them under laboratory conditions at 13°C and fed them *Artemia salina*. This produced a Q/B estimate of 40.15 yr^{-1}. This should be regarded as an upper limit due to the high temperature in which these euphausiids were reared. Jarre-Teichmann (1996) used a GE of 0.16 for krill in the Alaska Gyre. Purcell (1996) estimated a Q/B of 30 yr^{-1} for salps and used a GE of 0.3 for jellyfish in the Alaska Gyre.

An average Q/B of 19.5 yr^{-1} was estimated for the 3 euphausiid species (Sameoto 1976) and is used to represent the Q/B of the large zooplankton. This fits well with assuming a GE of 0.16, which would give a Q/B of 21.15 yr^{-1}. The value may seem a little high, but it allows for the average Q/B of the group to reflect the tunicates which are voracious consumers (Knoechel and Steel-Flynn 1989).

Small Zooplankton

There is minimal information on the Q/B values for copepods and other members of this group. Christensen (1995) assumed a gross efficiency of 0.3. Purcell (1996) estimated a Q/B of 90.4 yr^{-1} for small copepods in the Alaska Gyre, based on copepod ingestion and clearance rates. This value seems rather high. Assuming a GE of 0.3 would result in a Q/B of 20.67 yr^{-1}.

Diet

The two size classes of zooplankton feed on both autotrophic microplankton and heterotrophic microplankton, in addition to other diet components. However, in this model, both types of microplankton are grouped simply as phytoplankton. It is recognised that this ignores the dynamics of the microbial loop (Pomeroy 1979) and the potential contribution from the microbial loop to higher trophic levels. Thus, the diet of the small zooplankton would be mistakenly interpreted as herbivorous when taken at face value.

Large Zooplankton

Euphausiids eat detritus, phytoplankton, chaetognaths, amphipods and crustaceans (copepods) (Mauchline 1980). Chaetognaths eat copepods (Sullivan 1980) and jellyfish eat copepods (Smayda 1993). Since the relative proportions of these species in the large zooplankton group are unknown, a representative diet for the group might be 38% small zooplankton, 37% phytoplankton, 20% detritus and 5% cannibalism.

Small Zooplankton

The diet of the small zooplankton is assumed to be 100 % phytoplankton.

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30. Phytoplankton (Bundy and Caverhill)

Background

Most information on phytoplankton in 2J3KLNO is derived from a study carried out in 1980 under the auspices of the Mobil Oil company on the Grand Banks (Hollibaugh and Booth 1981). Arctic species of phytoplankton are associated with the inshore and offshore branches of the Labrador current, and are widespread over the banks in winter. Phytoplankton require light and nutrients and the main determinant of primary production is water stratification.

When the water column is unstratified, vertical mixing occurs and whilst there may be plentiful nutrients in the water column, phytoplankton may be vertically displaced from the euphotic zone. In a stratified water column, phytoplankton remain in the euphotic zone and have adequate light for photosynthesis and production. With time, however, stability can reduce the supply of nutrients causing a decrease in productivity. The onset of stratification on the Grand Banks occurs around April or May, when there is a spring bloom of diatom species such as *Chaetoceros decipiens* and *Thalassiosira* spp. Phytoplankton biomass and productivity decrease in June, due to depletion of nutrients and to predation by copepods (Hollibaugh and Booth 1981). Dinoflagellates and nanoflagellates are the main summer species. At this stage, there may be a significant amount of die off of phytoplankton, which will sink to the bottom and provide energy to benthic communities and/or be incorporated into the microbial food web (Turner and Roff 1993). The most significant feature of phytoplankton biomass and productivity is the narrow band of increased biomass and productivity along the shelf break stations (Hollibaugh and Booth 1981). Phytoplankton have rapid growth rates and show large spatial and temporal variability in biomass distribution (Hollibaugh and Booth 1981).

Biomass and production are the only two parameters required for the Ecopath model. There is no catch. There is no consumption and no diet because they are autotrophs.

Biomass

Phytoplankton biomass is measured as chlorophyll "a" biomass. On the Grand Bank three sources of information on chlorophyll "a" biomass were used: the Mobil study noted above; oceanographic research cruises carried out by the Bedford Institute of Oceanography (BIO) (Irwin *et al.* 1986, 1988; C. Caverhill *unpubl.*); and remote sensing, CZCS data (Feldman *et al.* 1995). On the Labrador Shelf area, two sources of information were used: the BIO research cruises (Irwin *et al.* 1989, 1990; C. Caverhill *unpubl.*) and the CZCS data.

The Mobil data came from a monthly series of research cruises where samples were taken from March 1980 to February 1981 across the Grand Bank. Other than the March 1980 sample of 12, all other monthly samples ranged in size from 40 - 55 observations. The BIO research cruises on the Grand Bank were carried out in April 1984 (n=4), May 1988 (n=1), May 1994 (n=2), May 1996 (n=2), May 1997 (n=3), July 1995 (n=3) and September 1985 (n=9). These were integrated over 50 m in order to compare them with the Mobil data and up to 100 m. The CZCS estimates of chlorophyll "a" are estimated from 8 years of data (1978-1986). The CZCS chlorophyll measure is taken as surface chlorophyll. This is then integrated over depth by using a stored chloropyll depth profile, which is based on monthly empirical ship-based studies for the region (for further explanation of the method, see Platt *et al.* 1991, Longhurst *et al.* 1995 and Sathyendranath *et al.* 1995).

There are large differences among the monthly values of these data sets (Table 14). This highlights both the variability of phytoplankton abundance and the differences in the methods used. The monthly CZCS chloropyll "a" data do not correspond at all with either the Mobil or BIO ship-based data. In the CZCS data there is no spring bloom but an early winter bloom. This would indicate that the CZCS data are not representative of the actual conditions, since a spring bloom is known to occur. For this reason the CZCS data are not used to estimate chlorophyll biomass for the Grand Bank.

The BIO ship-based chloropyll estimates are higher than the Mobil estimates in any given month. However, since these are representative of the period (including only the data from 1984-1988 would increase the May estimate), and since they are of a similar magnitude to the Labrador Shelf data below, these data were used to estimate biomass. These data cover only the months of April, May, August and September. In order to estimate a mean annual chlorophyll "a" biomass, it was assumed that the only significant difference between the 1984-1988 period represented by the BIO ship-based data and the 1980 period represented by the Mobil data was in the magnitude of the spring bloom. Thus the BIO ship-based values were used for April, May, August and September, and the Mobil values were used for the other months. Chlorophyll "a" biomass was then converted to phytoplankton biomass using a monthly Chl:C ratio (Hollibaugh and Booth 1981). This produced a mean average biomass of 24.6 $g \cdot m^{-2}$, ie., 24.6 $t \cdot km^{-2}$.

Table 14. Comparison of chlorophyll "a" biomass estimates from different sources for Grand Bank.

G. Bank	*Mobil Study*	*BIO Ship-based Data*		*CZCS*
MONTH	mg CHL·m^2 <=50m	mg CHL·m^2 <=50m	mg CHL·m^2 <=100m	mg CHL·m^2 <=100m
March	23.80			49.1
April	94.09	440.54	440.54	63.9
May	130.13	195.10	331.90	47.8
June	27.52			51.9
July	17.60	13.80	18.70	63.9
August	16.65			60.9
September	11.36	31.10	31.40	87.0
October	11.36			137.1
November	30.50			88.1
December	30.50			109.7
January	11.79			62.7
February	11.79			30.7

The CZCS data for the Labrador shelf show both a spring bloom and a fall bloom (Table 15) and thus is indicative of expected seasonal trends in phytoplankton biomass (Longhurst 1995). There are BIO ship-based data for May 1988 (n=7), May 1994 (n=2), May 1996 (n=4), May 1997 (n=3), June 1984 (n=9), June 1997 (n=3), July 1984 (n=3), July 1985 (n=4), July 1995 (n=5) and November 1995 (n=3). These data confirm both the trend and the magnitude shown in CZCS data. Both data sets were used to estimate the mean annual biomass. For the BIO ship-based data, the same procedure was followed as described for the Grand Bank. For the CZCS data, mean annual chlorophyll biomass was estimated as the mean of the monthly biomass. As above, chlorophyll "a" biomass was converted to phytoplankton biomass using a monthly Chl:C ratio (Hollibaugh and Booth 1981). The BIO ship-based data produced a mean annual phytoplankton biomass estimate of 28.4 $t \cdot km^{-2}$. The CZCS estimate was 29.8 $t \cdot km^{-2}$.

Table 15. Comparison of chlorophyll "a" biomass estimates from different sources for the Labrador Shelf.

Labrador Shelf MONTH	*BIO Ship-based Data* mg CHL·m^{-2} <=100m	*CZCS* mg CHL·m^{-2} <=100m
March		50.5
April		51.3
May	313.0	105.2
June	172.3	100.5
July	130.2	88.0
August		64.5
September		60.1
October		105.6
November	78.6	71.5
December		26.9
January		33.6
February		24.2

The mean biomass for the entire area was calculated as a mean of the two Labrador estimates and a weighted mean of this estimate and the estimate for the Grand Bank. This produced a total mean biomass estimate of 26.395 t·km^{-2}. The mean annual biomass estimate from the Mobil study for the Grand Bank was 11.593 t·km^{-2}. This is considerably lower than the estimate made here. Given the noted variability in phytoplankton biomass and distribution, it would be wise to use these two figures to represent a range of likely values for mean phytoplankton biomass in 2J3KLNO.

Primary Production

Primary productivity is estimated from the same data sources as described above. The CZCS data were not used for the Grand Bank, for the reasons given. The Mobil study estimated a primary productivity of 155.6 gC·m^{-2}·yr^{-1} for 1980-1981. Prasad and Haedrich (1993), using satellite data, estimated a primary production of 194 gC·m^{-2}·yr^{-1} for the same time period for the Grand Bank. There was only one ship-based estimate, in April 1984, of primary production. This was extrapolated to a yearly value on the basis of the Mobil data (that is, each month was raised by the difference between the corresponding month in the Mobil data and the Mobil April estimate). This produced an annual primary productivity of 482.4 gC·m^{-2}·yr^{-1}. However, this sample came from only one area, east of the Southeast Shoal region of Grand Bank, on the shelf break. Since productivity and biomass levels are known to be high on the shelf break (Hollibaugh and Booth 1981), this value is unlikely to be representative of mean productivity on Grand Bank.

For the Labrador shelf, the CZCS-based estimate of primary productivity was 429 gC·m^{-2}·yr^{-1} (Caverhill, unpubl.). The estimate is derived from the estimate of surface chlorophyll "a" biomass on the Labrador Shelf and the chlorophyll depth profiles (see above). A model is used to calculate surface light, then another model to compute how much light there is at each depth increment in the water column. Productivity by the chlorophyll at each depth and light level is estimated using stored ship-based photosynthesis parameters that are compiled by domain and season. Productivity at depth is then integrated over depth to the euphotic depth to give total productivity (see Platt *et al.* 1991; Longhurst *et al.* 1995; Sathyendranath *et al.* 1995).

Primary productivity data from BIO ship-based information were available for May 1988. This was raised to an annual figure using the Mobil data and the method described above for Grand Bank. The estimated annual productivity was 307.6 gC·m^{-2}·yr^{-1}.

The productivity estimates for Grand Bank range from 155.6 to 194 gC·m^{-2}·yr^{-1}, and for the Labrador shelf from 307.6 to 426 gC·m^{-2}·yr^{-1}. The Mobil study and the Prasad and Haedrich (1993) estimates are lower than the ship-based or CZCS estimates, but are based (in the case of the Mobil data) on monthly samples across the Grand Bank over one year. The BIO ship-based samples are based on data for one month only. The CZCS data for the Labrador Shelf include data for all months over several years. The high BIO ship-based estimate for Grand Bank from the shelf break should not be used, for the reasons given above. However, all the other estimates are valid estimates of productivity. The range of estimates is given in Table 16 below.

Table 16. Primary productivity and P/B estimates for Grand Bank and the Labrador Shelf.

	Grand Bank		*Labrador Shelf*	
	Low	High	Low	High
PP(gC·cm^{-2})	155.6	194.0	307.6	429.0
PP(t·km^{-2})	1556.3	1940.0	3076.0	4290.0
Biomass (t·km^{-2})	24.6	24.6	29.1	29.1
P/B (yr^{-1})	63.3	78.9	105.7	147.3

The P/B ratios are estimated using the biomasses derived above. The range is wide, from 63 to 147 yr^{-1}, and the mean weighted P/B is 93.1. The Mobil biomass estimate for the Grand Bank (11.6 yr^{-1}) gives a higher P/B of 134.2 to 167.2 yr^{-1}. There is considerable uncertainty concerning the P/B ratio, and an initial value of 93.1 yr^{-1} is used, although it may be higher than this.

31. Detritus

The detritus biomass was estimated using an empirical relationship derived by Pauly *et al.* (1993). It relates detritus biomass to primary productivity and euphotic depth.

$$\log_{10} D = -2.41 + 0.954 \log_{10} PP + 0.863 \log_{10} E \qquad (4)$$

where,
D = detritus standing stock (gC·m^{-2} (grams of carbon per square metre)), PP = primary productivity (gCm^{-2} year^{-1}), E = euphotic depth (m).

The fit of the regression equation to the data is not very good, but as suggested by Pauly *et al.* (1993:13), it "might be considered sufficient in cases where no other information is available".

Primary production was described above. The annual range is 155.6 $gC\cdot m^{-2}$ to 483.4 $gC\cdot m^{-2}$.

The euphotic depth is calculated from the Beer-Bouger Law where,

$$\ln I(1) - \ln I(2) = k\,(D(2)-D(1)) \tag{5}$$

and,
I (1) = 100% irradiance (at the surface), I(2) = 1% irradiance (at the euphotic depth), D (1) = depth at surface (0 m), D(2) = euphotic depth, k = light attenuation co-efficient.

Seasonal values of the light attenuation co-efficient for 1980 on Grand Bank were taken from Hollibaugh and Booth (1981, Table 4_2). The average value was substituted into equation (5) and the mean annual euphotic depth on the Grand Bank estimated as 54.7 m.

This euphotic depth and the two extremes of the PP estimates were substituted into equation (4) giving a range of detritus biomass estimates from 14.9 $gC\cdot m^{-2}$ to 38.9 $gC\cdot m^{-2}$, or 149 $t\cdot km^{-2}$ to 389 $t\cdot km^{-2}$, using a conversion factor of 10 g wet weight = 1 gC (Christensen and Pauly 1992:20). This range is wide and applies only to Grand Bank. Given the approximate nature of the estimation method, the range should be regarded as a gross approximation. For the purposes of the Ecopath model, a midprange of 26.9 $t\cdot km^{-2}$ is used as the detritus biomass estimate.

Results

The Unbalanced Model

Table 17 shows the main model results and Table 18 gives the breakdown of mortality for each group. The model is not balanced; there are negative flows to the detritus and some ecotrophic efficiencies (EE) are greater than 1. EE is the proportion of production that is passed up the food web, that is, consumed or harvested. If EE is greater than 1, then the consumption of group *i* is greater than its production. Two components can contribute to high EE's: high consumption rate and/or biomass of the predator, and low production rate and/or biomass of the prey. The EE of the following groups was greater than 1: cod ≤ 35cm, Greenland halibut ≤ 40 cm, flounders, redfish, small demersal feeders, sand lance, piscivorous small pelagic feeders, planktivorous small pelagic feeders, shrimp, large crustacea, large zooplankton and small zooplankton. The total biomass of harvested fish species is 27.39 $t\cdot km^{-2}$.

The total mortality for each group is equivalent to the P/B ratio. The fishing mortality is calculated as the catch divided by the biomass. Predation mortality, M2, is calculated as the consumption of each group (total predator catch) divided by biomass. The "other mortality", which is attributed to disease, starvation and old age, is estimated by the model (and is equivalent to 1 – EE) and balances the mortalities so that $Z = F + M2 + MO$. In Table 18, many of the MOs are negative. This is another indication that the model is not balanced, and that M2 must be reduced.

There are several key predators in this system. The mortality accounted for by the top vertebrate predators is shown in Figure 5 for all prey (a) and for vertebrate prey (b). Cod > 35 cm, harp seals and skates account for almost 50 % of total mortality imposed by vertebrate predators on all prey. Harp seals, cod > 35 cm and whales account for over 50 % of total mortality imposed by vertebrate predators on vertebrate prey. From the fish point of view then, these are the main predators. Skates, hooded seals and Greenland halibut > 40 cm are also important predators. The impact of these predators on the groups whose EE is greater than 1 is shown in Table 19.

Harp seals, hooded seals, cod > 35 cm, whales and skates account for over 80 % of the total predation mortality on cod ≤ 35 cm, Greenland halibut < 40 cm, flounders and redfish. For the small demersal feeders, American plaice ≤ 35 cm and large demersal feeders are important predators in addition to the predators noted above. Capelin, cod > 35 cm and American plaice are the most important predators on sand lance. Whales impose a significant predation mortality on the piscivorous small pelagic feeders, while harp seals are also an important predator. The greatest predation on shrimp is by cod > 35 cm, followed by large demersal feeders and harp seals. Predation on large crustaceans is largely by skates, cod > 35 cm and cannibalism. The principal predators of large zooplankton and small zooplankton are capelin and large zooplankton.

Ecopath is a top-down model, so model estimates are determined by the biomass and consumption rates of the top predators. Either these are too high for the predators highlighted in Table 19 or the P/B rates of the prey groups are too low. Both possibilities may be contributing to the imbalances.

Table 17. Results of the first (unbalanced) Ecopath model of Newfoundland-Labrador, NAFO divisions 2J3KLNO, 1985-1987.

Group Name	*Biomass ($t \cdot km^{-2}$)*	*P/B (yr^{-1})*	*Q/B (yr^{-1})*	*EE*	*GE*	*Harvest ($t \cdot km^{-2}$)*	*Flow to Detritus ($t \cdot km^{-2}$)*	*Trophic Level*
1. Whales	0.25	0.10	11.79	0	0.008	0	0.62	4.24
2. Harp Seals	0.18	0.10	17.41	0.05	0.006	0.001	0.66	4.36
3. Hooded Seals	0.03	0.11	13.10	0	0.008	0	0.09	4.68
4. Seabirds	0.01	0.25	54.75	0.33	0.005	0.001	0.13	4.20
5. Cod > 35 cm	2.04	0.65	3.24	0.52	0.201	0.603	1.97	4.16
6. Cod <= 35 cm	0.09	0.60	6.09	7.74	0.099	0	-0.27	3.87
7. G.halibut >40 cm	0.35	0.51	1.48	0.36	0.344	0.035	0.22	4.53
8. G.halibut <=40 cm	0.16	0.25	3.40	9.64	0.073	0.002	-0.24	4.25
9. Aplaice >35 cm	0.97	0.54	1.26	0.19	0.426	0.100	0.67	3.66
10. Aplaice <=35 cm	0.78	0.63	3.74	0.53	0.167	0.025	0.82	3.70
11. Flounders	0.87	0.39	3.60	1.15	0.109	0.079	0.57	3.09
12. Skates	0.52	0.29	2.88	0.26	0.099	0.037	0.41	4.15
13. Redfish	0.98	0.33	2.00	1.79	0.165	0.178	0.14	3.66
14. L.Dem.Feeders	0.85	0.26	1.75	0.68	0.150	0.052	0.37	3.44
15. S.Dem.Feeders	0.23	0.30	2.00	15.14	0.150	0	-0.87	3.11
16. Capelin	13.29	1.15	6.39	0.74	0.179	0.126	20.96	3.27
17. Sand lance	2.10	1.15	7.67	1.20	0.150	0	2.75	3.20
18. Arctic cod	2.73	0.40	2.63	0.91	0.150	0	1.53	3.41
19. L.Pel.Feeders	0.03	0.40	3.33	0.95	0.120	0.006	0.02	4.24
20. Pisc. SPF	0.45	0.27	1.77	6.81	0.150	0.015	-0.54	4.14
21. Plankt. SPF	0.95	0.24	1.60	4.38	0.150	0.019	-0.47	3.30
22. Shrimp	0.20	1.45	9.67	2.76	0.150	0.004	-0.12	2.46
23. Large Crustacea	0.19	0.28	5.85	20.87	0.048	0.016	-0.82	3.13
24. Echinoderms	112.30	0.60	6.67	0.02	0.090	0	215.67	2.00
25. Molluscs	42.10	0.57	6.33	0.04	0.090	0	76.48	2.00
26. Polychaetes	10.50	2.00	22.22	0.12	0.090	0	65.23	2.00
27. O.Benthic Inver	7.80	2.50	12.50	0.12	0.200	0	36.76	2.00
28. L.Zooplankton	18.34	3.43	19.50	1.10	0.176	0	65.58	2.56
29. S.Zooplankton	21.70	6.20	20.67	1.73	0.300	0	-8.45	2.00
30. Phytoplankton	26.86	93.10	0	0.23	-	0	1919.68	1.00
31. Detritus	389.00	-	-	0.58	-	0	-	1.00

Table 18. Distribution of different types of mortality on the Ecopath groups (yr^{-1}). Z = total mortality, F = fishing mortality, MO = other mortality and M2 = predation mortality.

Group Name	*Z*	*F*	*MO*	*M2*
1. Whales	0.10	0	0.10	0
2. Harp Seals	0.10	0.01	0.10	0
3. Hooded Seals	0.11	0	0.11	0
4. Seabirds	0.25	0.08	0.17	0
5. Cod > 35 cm	0.65	0.30	0.32	0.04
6. Cod <= 35 cm	0.60	0	-4.05	4.65
7. G.halibut >40 cm	0.51	0.10	0.32	0.08
8. G.halibut <=40 cm	0.25	0.01	-2.13	2.37
9. Aplaice >35 cm	0.54	0.10	0.44	0
10. Aplaice <=35 cm	0.63	0.03	0.29	0.30
11. Flounders	0.39	0.09	-0.06	0.36
12. Skates	0.29	0.07	0.21	0
13. Redfish	0.33	0.18	-0.26	0.41
14. L.Dem.Feeders	0.26	0.06	0.08	0.12
15. S.Dem.Feeders	0.30	0	-4.24	4.54
16. Capelin	1.15	0.01	0.30	0.84
17. Sand lance	1.15	0	-0.23	1.38
18. Arctic cod	0.40	0	0.03	0.36
19. L.Pel.Feeders	0.40	0.21	0.02	0.17
20. Pisc. SPF	0.27	0.03	-1.54	1.77
21. Plankt. SPF	0.24	0.02	-0.81	1.03
22. Shrimp	1.45	0.02	-2.55	3.98
23. Large Crustacea	0.28	0.09	-5.60	5.80
24. Echinoderms	0.60	0	0.59	0.01
25. Molluscs	0.57	0	0.55	0.02
26. Polychaetes	2.00	0	1.77	0.23
27. O.Benthic Inver	2.50	0	2.21	0.29
28. L.Zooplankton	3.43	0	-0.32	3.76
29. S.Zooplankton	6.20	0	-4.52	10.72
30. Phytoplankton	93.10	0	71.47	21.63

Table 19. Predator mortality on individual prey groups (yr^{-1}). Predators in bold account for 80 % + of the mortality on each prey.

	PREY											
PREDATORS	*6 Cod <= 35 cm*	*8 G.halibut <=40cm*	*11 Flounders*	*13 Redfish*	*15 S.Dem. Feeders*	*17 Sand lance*	*20 Pisc SPF*	*21 Plankt. SPF*	*22 Shrimp*	*23 L.C.*	*28 LZP*	*29 SZP*
1. Whales	**0.38**				**0.43**	0.07	**1.07**	**0.09**			0.02	0.01
2. Harp Seals	**1.16**	**0.87**	**0.18**	0.02	**0.66**	**0.14**	**0.36**	**0.13**	**0.57**		0.01	
3. Hooded Seals		**0.78**	**0.11**	0.02	0.24		0.03	**0.07**				
4. Seabirds	0.03				0.05	0.02	0.02	0.02	0.02		0	0
5. Cod > 35 cm	**1.27**	0.24	0.01	**0.06**	**1.17**	**0.33**	0.01	0.03	**1.21**	**1.72**	0.02	
6. Cod <= 35 cm	0.04	0.01			0.06	0.01	0.01	0.01	**0.22**	0.07	0.01	
7. G.halibut >40 cm	**0.42**	**0.40**	0	**0.14**	0.19		0.01	0.01	0.03		0	
8. G.halibut <=40 cm	0.05	0.02			0.02		0.01	0.02	0.06		0	
9. Aplaice >35 cm		0.01			0.05	**0.10**			0.02	0.30	0	
10. Aplaice <=35 cm	0.12	0.04	0.03	0	**0.30**	**0.13**			0.19	0.33	0.01	
11. Flounders					0.10	0.04			0.11		0	
12. Skates	**0.79**	0.01	0.01	**0.13**	**0.73**	0.10	0.19	0.01	0.16	**2.50**	0	0
13. Redfish	0.04			0.01	0.01	0		**0.50**	**0.34**		0.06	0.01
14. L.Dem.Feeders	0.17		0.02	0.02	**0.27**	0.02	0	0.05	**0.66**	0.21	0.01	0
15. S.Dem.Feeders					0.02	0	0	0	0.04	0.02	0	0
16. Capelin						**0.40**					**2.01**	**2.14**
17. Sand lance											0.31	0.48
18. Arctic cod											0.25	0.11
19. L.Pel.Feeders	0			0	0.01	0	0.06	0.02	0.01		0	0
20. Pisc. SPF	0.16					0		**0.07**	0.03		0.01	0
21. Plankt. SPF									0.04		0.04	0.03
22. Shrimp											0.01	0.02
23. Large Crustacea					0.24				**0.26**	**0.65**	0	0
28. L.Zooplankton											**0.98**	**7.91**
TOTAL	4.63	2.38	0.36	0.40	4.55	1.36	1.77	1.03	3.97	5.8	3.75	10.71

The quality of the data used for each group in the model is variable. For some, there are empirical estimates available from samples taken from within the model area and time frame (e.g., cod > 35 cm, harp seals). For others, it was necessary to use empirical data from other areas and/or time frames (e.g., flounders, skate) or less specific information (e.g., whales, redfish, large pelagic feeders).

The groups with the most reliable data are the predator groups, specifically harp seals, cod > 35 cm and Greenland halibut > 40 cm. Of the prey groups, cod < 35 cm are probably the best studied, but our knowledge about the biomass, production and consumption of any of these groups is poor. For example, for the young cod and Greenland halibut, there is uncertainty concerning numbers-at-age, actual mortality with age or size and mean weight at age, all of which are fundamental to the calculations made to estimate biomass.

This means that greater confidence is placed on the consumption demands by the predators than on the biomass of prey estimated to meet these demands. That is, the balance of the Ecopath model should be constrained to meet the consumption requirements of the groups for which we have the most certainty about the parameter estimates. It is a robust finding that many large ecosystem energetic models do not balance the consumption of the top predators with the production of prey (e.g., Mills and Fournier 1979; Jones 1984; Welch *et al.* 1992).

Other problems with the initial model

In addition to the basic imbalance of the model, there were some inconsistencies in the gross efficiencies, GE. GE is the ratio of production to consumption and for most groups should have values between 0.1 and 0.3 (Christensen and Pauly 1992). The marine mammals and the seabirds are exceptions. Once these animals reach maturity their growth efficiency is very low (Gaskin 1982). This is seen in Table 17.

Cod ≤ 35 cm, Greenland halibut ≤ 40 cm, and large crustaceans also have low gross efficiencies. This could be due to either low production or high consumption. In order to increase the large crustacean gross efficiency of 0.048, the production estimate was increased to the maximum of the range (0.382 yr^{-1}) and the consumption estimate was reduced to the minimum of the range (4.42 yr^{-1}). This produced a GE estimate of 0.08, which is similar to estimates made by Jarre-Teichmann and Guenette (1996). For cod ≤ 35 cm and Greenland halibut ≤ 40 cm, the GEs were altered in the process of reducing EE to less than zero, see below.

The gross efficiencies of Greenland halibut ≤ 40 cm and American plaice > 35 cm were too high. In the case of the Greenland halibut, the P/B ratio was uncertain, with a described range of 0.296 to 0.719 yr^{-1}. A mid-point was used above. However, since this results in a GE that is too large, this indicates that the lower end of the range is more likely. For this reason the P/B of 0.296 yr^{-1} (estimated by assuming P=M*B+C) was used, giving a GE of 0.200.

For American plaice, the P/B estimate was derived from catch curve analysis and considered better determined than the Q/B estimate. The Q/B estimate was estimated from Zammaro's (1992) work on the Tail of the Grand Bank. The value of 1.262 yr^{-1} was raised to 2.0 yr^{-1}, an increase of almost 60 %, giving a GE of 0.269 yr^{-1}.

Addressing imbalances in the model

The first step to balance the model is to reduce the EE's to less than 1 for all the groups with EE > 1. It was noted above that the data for these groups is not as certain as the data for the top predators (cod > 35 cm and harp seal). Thus, the rationale used is to alter the input parameters (biomass or production) of the prey groups to produce EE's of less than 1.

Cod ≤ 35 cm

The biomass of small cod was estimated by back-calculating from numbers at age 3. The mean number at age 3 (on Jan 1) was $224{,}394 * 10^3$, and the natural mortality was assumed as 0.6 for all age groups. The biomass was raised here by altering the assumptions made about natural mortality and numbers at age 3. Natural mortality was raised to 0.65 on age 2, 1.2 on age 1 and 3.0 on age 0. In addition, the number at age 3 was raised by a factor of 2. It was assumed that the sequential population analysis (Shelton *et al.* 1996b) underestimates the number of these fish since it used a natural mortality of 0.2 for all ages.

The results of the back-calculation are shown in Table 20. A biomass of 168,112 t is equivalent to 0.340 $t{\cdot}km^{-2}$. Since mortality at age was increased, the mean M, and therefore P/B, was also increased to 1.597 yr^{-1}. When this biomass and P/B are re-entered in the model, EE is 0.923 and the GE is 0.201.

Table 20. Back-calculation of cod ≤ 35 cm biomass.

AGE	*M* yr^{-1}	*Nos (000's) (mid year)*	*Mn wt (kg)*	*Biomass (t)*	*W'ted mean M*
3		[1]448,789			
2	0.65	605,801	0.100	60,580	0.216
1	1.20	2,011,331	0.025	50,283	0.359
0	3.00	19,082,980	0.003	57,249	1.022
SUM		21,700,112		168,112	1.597

[1] Numbers on Jan 1st, raised by 2

Greenland halibut ≤ 40 cm

The biomass of small Greenland halibut was estimated by back-calculating from numbers-at-age 6. The mean numbers at age 6 (from the fall RV Survey) was $105{,}135 * 10^3$, and the natural mortality was assumed to be 0.2 on ages 3-6 and 0.6 on ages 0-2. As above, the biomass was raised by altering the assumptions made about natural mortality and numbers-at-age. Natural mortality was raised to 0.4 on ages 3-6 and to 1.6 on ages 0 to 2. In addition, the number at age 6 was raised by a factor of 1.4. For Greenland halibut, the numbers at age were derived from an RV survey. It is assumed that the catchability of the survey was not 1, and that it may have been around 0.7.

The results of the back-calculation are shown in Table 21. A biomass of 247,165 t is equivalent to 0.499 $t{\cdot}km^{-2}$. Since mortality-at-age was increased, the mean M, and therefore P/B, was also increased to 0.872 yr^{-1}. Q/B also changed, since it is estimated using mean weight-at-age, to 4.476 yr^{-1}. When the new biomass, P/B, and Q/B are re-entered in the model, EE is 0.931 and the GE is 0.195.

Table 21. Back-calculation of Greenland halibut ≤ 40 cm biomass.

AGE	M	Nos (000's)	Mn wt (kg)	Biomass (t)	W'ted Z
6	0.4	116,192			
5	0.4	173,339	0.386	66,909	0.108
4	0.4	258,591	0.191	49,505	0.080
3	0.4	385,772	0.087	33,494	0.054
2	1.6	1,910,741	0.028	54,432	0.352
1	1.6	9,463,964	0.004	40,118	0.260
0	1.6	31,421465	8.618E-05	2,708	0.018
SUM		43,730,064		247,165	0.872

Flounders

The yellowtail flounder biomass was estimated as the Campelen converted biomass for 7+ fish and the backcalculated biomass at age for ages 0 to 6. The ratio between young and old fish was then used to estimate biomass of witch flounder ages 0 to 6. Biomass was re-estimated for the younger age groups, using an M of 0.9 for ages 0 to 2, and assuming a catchability of 0.7 for age 6 fish in the RV survey. This produced a total flounder biomass of 551,362 t, 1.114 t·km^{-2}. The P/B ratio is decreased slightly to 0.372 yr^{-1} (from 0.394 yr^{-1}), and the EE is 0.949.

Table 22. Re-estimated flounder biomass

	Yellowtail Flounder	Witch	Winter	Flounders
Campelen Biomass 7+	105,490	53,975		159,465
Backcalculated Biomass (0-6)	242,949	124,308		367,257
B from catch assumption			24,640	24,640
Total	348,439	178,283	24,640	551,362

Redfish

The EE of the redfish was too high. However, the main predator of redfish is Greenland halibut < 40 cm, and its diet is considered more reliable than the parameters derived for the redfish, which are poorly known. EE was set equal to 0.95 and the biomass was estimated by the Ecopath model as 1.876 t·km^{-2}.

Small demersal feeders

This is a mixed group of small demersal feeding fish, including the juveniles of the large demersal feeders. It is poorly defined and consumption is estimated by assuming a GE of 0.15. EE was very high. In order to reduce EE, production was first increased to the maximum of the range, from 0.3 to 0.4 year^{-1} (this has the effect of increasing GE to 2). There was no rational for increasing the biomass, so the EE was made equal to 0.95, and the biomass estimated by the model. The required biomass was 5.06 t·km^{-2}.

Sand lance

The biomass of this group was a gross approximation. EE was set to 0.95 and biomass estimated from the model. The required biomass was 2.692 t·km^{-2}.

Piscivorous Small Pelagic Feeders

The P/B of this group was raised to 0.6 yr^{-1} from 0.265 yr^{-1} since the large pelagic feeders had a P/B of 0.4 and smaller fish would be expected to have a higher P/B ratio. The ecotrophic efficiency was set to 0.95. The model estimated a biomass of 1.509 t·km^{-2} and a GE of 0.34. The higher estimate for GE agrees with the gross conversion efficiency estimate for squid in O'Dor and Dawe (1998).

Planktivorous Small Pelagic Feeders

The P/B of this group was raised to 0.5 yr^{-1} from 0.265 yr^{-1} since the large pelagic feeders had a P/B of 0.4 and smaller fish would be expected to have a higher P/B ratio. The ecotrophic efficiency was set to 0.95. The model estimated a biomass of 3.568 t·km^{-2} and a Q/B of 3.33 yr^{-1}.

Shrimp

The EE of shrimp was set equal to 0.95 and a biomass of 1.459 t·km^{-2} estimated by the model.

Large Crustaceans

The large crustaceans are a mixed group comprising crabs and lobsters. Using the method employed above, that is, allowing biomass to be estimated by the model, resulted in an extremely large estimate due to cannibalism within the group. Large crustaceans made up 11 % of the diet. Only a small part of this is likely to be real cannibalism. Most will be one species of crab eating another species of crab. There are two ways to resolve this problem. One is to create two large crustacean groups, one predator and one prey. However, there is insufficient information to do this. The other short cut approach is to reduce cannibalism. Cannibalism was reduced to 1 % of the diet and the difference distributed over the echinoderms, molluscs, polychaetes and other benthic invertebrates by their relative weights.

When the ecotrophic efficiency was set to 0.95, the model estimated a biomass of 3.548 t·km^{-2}. This is still more than an order of magnitude greater than the original estimate.

Large Zooplankton

EE was set equal to 0.95 and a biomass of 22.46 t·km^{-2} estimated by the model.

Small Zooplankton

Production of the small zooplankton was increased from 6.2 to 8.4 yr^{-1}, the maximum of the range. Since GE was set equal to 0.15, this resulted in an increase in consumption biomass ratio from 20.67 to 28 year $^{-1}$. EE was set equal to 0.95 and a biomass of 33.67 t·km^{-2} estimated by the model.

Changes to other groups

Arctic Cod

Arctic cod was not among the original set of groups that were out of balance. However, predation on this group increased due to the increased biomass of cod $\leq$ 35 cm and Greenland halibut $\leq$ 40 cm. In order to redress this imbalance, the biomass was increased by 10 %. In addition, the P/B was re-estimated as the weighted average mortality of the 1 to 2 years olds and the 2 to 3 years olds, assuming the ratio was 3:1, to better reflect the preponderance of 1 and 2 year old Arctic cod in 2J3KLNO (Lilly *et al.* 1994). This produced a biomass of 1,485,785 t, 3.0 $t \cdot km^{-2}$, a P/B of 0.402 yr^{-1} and an EE of 0.967.

Capelin

Predation on capelin also increased as a result of the increased biomass estimates of cod $\leq$ 35 cm, Greenland halibut $\leq$ 40 cm and piscivorous small pelagic feeders. EE was set to 0.95 and the model estimated a biomass of 13.61 $t \cdot km^{-2}$. In addition, capelin consumption was reduced from a Q/B of 6.4 to 4.3 $year^{-1}$. The original estimate was based on the fish eating 3 % body weight per day. However, this produced a Q/B larger than the small pelagics and this was considered to be unlikely. The effect of reducing Q/B is to reduce predation on their zooplankton prey.

Model 1 - The first balanced model

The input parameters and selected results of the balanced model are shown in Table 23. The balanced model, under the assumptions described above, produced a total finfish biomass of 38.8 $t \cdot km^{-2}$, 41 % higher than the original estimate. Since biomass estimates of the lower trophic levels were raised to meet the consumption requirements of the top predators, this result was predictable. It indicates that there may be a greater fish biomass in 2J3KLNO than has been previously estimated. This result is typical of large scale ecosystem energetics models.

The changes made to the consumption and production estimates were discussed above and all were within the original range of estimates described for the model. However, many of the biomasses in Table 23 were estimated by the model, that is, they are the biomasses required to balance the model. These biomass estimates are discussed below to determine whether they are feasible. The percentage differences in biomass estimated by the unbalanced and balanced model are shown in Figure 6.

Table 23. Input parameters and selected results of the balanced Newfoundland-Labrador model, NAFO divisions 2J3KLNO, 1985-1987.

Group Name	*Biomass (t·km^{-2})*	*P/B (yr^{-1})*	*Q/B (yr^{-1})*	*EE*	*GE*	*Harvest (t·km^{-2})*	*Flow to Detritus (t·km^{-2})*	*Trophic Level*
1. Whales	0.25	0.10	11.79	0	0.008	0	0.62	4.24
2. Harp Seals	0.18	0.10	17.41	0.05	0.006	0.001	0.66	4.36
3. Hooded Seals	0.03	0.11	13.10	0	0.008	0	0.09	4.68
4. Seabirds	0.01	0.25	54.75	0.33	0.005	0.001	0.13	4.20
5. Cod > 35cm	2.04	0.65	3.24	0.52	0.201	0.603	1.97	4.16
6. Cod <= 35 cm	0.34	1.60	6.09	0.92	0.262	0	0.46	3.87
7. G.halibut >40 cm	0.35	0.30	1.48	0.62	0.200	0.035	0.14	4.53
8. G.halibut <=40 cm	0.50	0.87	4.48	0.93	0.195	0.002	0.48	4.25
9. Aplaice >35 cm	0.97	0.54	2.00	0.19	0.269	0.100	0.71	3.65
10. Aplaice <=35 cm	0.78	0.63	3.74	0.53	0.167	0.025	0.82	3.70
11. Flounders	1.11	0.37	3.60	0.95	0.103	0.079	0.82	3.09
12. Skates	0.52	0.29	2.88	0.26	0.099	0.037	0.41	4.11
13. Redfish	1.88	0.33	2.00	0.95	0.165	0.178	0.78	3.66
14. L.Dem.Feeders	0.85	0.26	1.75	0.68	0.150	0.052	0.37	3.44
15. S.Dem.Feeders	5.06	0.40	2.00	0.95	0.200	0	2.13	3.11
16. Capelin	13.61	1.15	4.30	0.95	0.266	0.126	12.49	3.27
17. Sand lance	2.69	1.15	7.67	0.95	0.150	0	4.28	3.20
18. Arctic cod	3.00	0.40	2.63	0.97	0.153	0	1.62	3.41
19. L.Pel.Feeders	0.03	0.40	3.33	0.95	0.120	0.006	0.02	4.24
20. Pisc. SPF	1.51	0.6	1.77	0.95	0.150	0.015	0.58	4.14
21. Plankt. SPF	3.57	0.5	3.33	0.95	0.340	0.019	2.47	3.30
22. Shrimp	1.46	1.45	9.67	0.95	0.150	0.004	2.93	2.46
23. Large Crustacea	3.55	0.38	4.42	0.95	0.086	0.016	3.20	3.02
24. Echinoderms	112.30	0.60	6.67	0.10	0.090	0	210.60	2.00
25. Molluscs	42.10	0.57	6.33	0.20	0.090	0	72.53	2.00
26. Polychaetes	10.50	2.00	22.22	0.38	0.090	0	59.80	2.00
27. O.Benthic Inver	7.80	2.50	12.50	0.42	0.200	0	30.76	2.00
28. L.Zooplankton	22.46	3.43	19.50	0.95	0.176	0	91.45	2.56
29. S.Zooplankton	33.67	8.40	20.67	0.95	0.406	0	153.31	2.00
30. Phytoplankton	26.86	93.10	0	0.34	-	0	1641.55	1.00
31. Detritus	389.00	-	-	0.61	-	0	-	1.00

Biomass

Cod ≤ 35 cm, Greenland halibut ≤ 40 cm, Flounders

The biomasses of these groups were re-estimated using the back-calculation method. Tables 20 and 21 detailed the assumptions necessary to generate the required 200-300 % biomass increases in cod ≤ 35 cm and Greenland halibut ≤ 40 cm (Figure 6). The biomass generated by the back-calculation method is sensitive to natural mortality at age when it is greater than 1. Since such high mortalities are necessary on the youngest age groups of fish, these biomasses should be regarded as rough approximations only.

Predation on cod ≤ 35 cm is shown in Table 24. Cannibalism by larger cod and predation by harp seals are the largest sources of mortality, accounting for 46 % of the total morality. Skates and piscivorous small pelagic feeders are also important predators. The pattern of predation is similar to the unbalanced model (Table 19), with the exception that piscivorous small pelagic feeders have gained importance as predators. Their biomass has increased by an order of magnitude to accommodate the consumption requirements of whales and harp seals. It is possible that this biomass is over-estimated (see below) and this would affect the biomass estimated for cod ≤ 35 cm. However, since the main predators, cod > 35 cm and harp seals, are relatively well parameterised in this model, it is reasonable to assume that the biomass estimated for cod ≤ 35 cm is of the correct magnitude.

Table 24. Composition of predation mortality on cod ≤ 35 cm.

Predator	*Mortality (yr^{-1})*	*percentage*
Cod > 35cm	0.35	24.0
Harp Seals	0.32	21.9
Skates	0.22	15.1
Pisc. SPF	0.15	10.3
G.halibut >40 cm	0.11	7.5
Whales	0.10	6.8
Others	0.20	14.4
Total	1.46	100.0

The main predators of Greenland halibut ≤ 40 cm are hooded seals and harp seals (Table 25). Cannibalism and predation by cod > 35 cm are also important sources of mortality. This pattern is the same as that seen in the unbalanced model. Again, since these predators are relatively well parameterised is it reasonable to assume that the estimated biomass for Greenland halibut ≤ 40 cm is approximately correct.

Harp seals and hooded seals are also the main predators of the flounder group (Table 26). Fishing mortality also contributes to this group, making the total mortality caused by these 3 predators 85.7 %. Again, this pattern of mortality is similar to that in the unbalanced model (Table 19). All three predators are well parameterised and thus the assumption is that the estimated biomass is approximately correct.

Table 25. Composition of predation mortality on Greenland halibut ≤ 40 cm.

Predator	*Mortality (yr^{-1})*	*percentage*
Harp Seals	0.29	36.3
Hooded Seals	0.26	32.5
G.halibut >40 cm	0.13	16.3
Cod > 35cm	0.08	10.0
Others	0.04	5.0
Total	0.80	100.0

Table 26. Composition of predation mortality on flounders.

Predator	*Mortality (yr^{-1})*	*percentage*
Harp Seals	0.14	40.0
Hooded Seals	0.09	25.7
Fishing	0.07	20.0
Others	0.05	14.3
Total	0.35	100.0

Redfish

The redfish biomass estimated by the model was almost twice the original estimate. The original biomass estimate was based on a range of surveys, both Canadian and Russian. Divisions 2J3K and 3L were reasonably surveyed, but 3NO was not. The original estimate may be too low for the following reasons: the conversion between Campelen, Engels and Russian survey data may be inaccurate and/or the biomass estimate does not allow for catchability, i.e., it is the trawlable biomass. Edwards (1968) estimated a catchability of 0.27 for redfish (using Yankee 36). If a catchability of 0.5 is assumed here, assuming that the Campelen gear is twice as efficient as the Yankee 36, then the redfish biomass required by the model is obtained.

The main predators of redfish are shown in Table 27. Over 60 % of this mortality is imposed by the fishery, Greenland halibut > 40 cm, and cod > 35 cm, groups for which there is reasonably good parameter definition. Thus the biomass estimated to meet consumption demands is likely to be a reasonable approximation.

Table 27. Composition of predation mortality on redfish.

Predator	*Mortality (yr^{-1})*	*percentage*
Fishing	0.09	30.0
G.halibut>40cm	0.07	23.3
Skates	0.07	23.3
Cod > 35cm	0.03	10
Others	0.04	13.3
Total	0.30	100.0

Small demersal feeders

The original biomass of this group was estimated as the sum of the trawlable biomass for all species in the group. This was then raised to a Campelen equivalent, using the biomass ratio between Engels 1993/94 and Campelen 1996/1997 (see above). However, the biomass required to balance the Ecopath model (2,504,700 t) is twenty-two times the original estimate. This large biomass is difficult to recreate with existing data. Catchability of these species is low, but it would have to be as low as 0.045 for the Campelen gear or 0.004 for the Engels gear in order to raise the trawlable biomass to the value of the required biomass estimated by the Ecopath model.

The large biomass of small demersal feeders is driven by the consumption demands of the large crustaceans, which account for over 41 % of the total mortality (Table 28). This high mortality is a result of the large biomass estimated for the large crustaceans. This estimate is uncertain, see below. If the large crustacean diet is altered so that small demersal feeders are no longer eaten, the biomass estimate is reduced to 1,424,610 t, a biomass 1 million tonnes lower than the estimate above. Small demersal feeders constitute only 5 % of the diet of large crustaceans, and thus the sensitivity of the small demersal feeders to the biomass of the large crustacea is very high. This is discussed further below. Of the total of 13 groups that prey on the small demersal feeders, there is also high uncertainty over the biomass (and thus consumption requirements) of skates and whales.

Table 28. Composition of predation mortality on small demersal feeders.

Predator	*Mortality (yr^{-1})*	*percentage*
Large Crustacea	0.15	41.7
Cod > 35cm	0.05	13.9
Harp Seals	0.03	8.3
Skates	0.03	8.3
Whales	0.02	5.6
S.Dem.Feeders	0.02	5.6
Others	0.06	16.7
Total	0.36	100.0

Capelin

The biomass of capelin required by the Ecopath model was 6,738,930 t while the original estimate was 6,578,068 t. This represents a minor increase, which is feasible, given the range of estimates described earlier.

Capelin is described as a forage fish, and Table 29 amply demonstrates this point. There are 15 groups which prey on capelin, plus fishing, which is not an important source of mortality. The main predators are cod > 35 cm, piscivorous small pelagic feeders, Greenland halibut ≤ 40 cm and whales.

Table 29. Composition of predation mortality on capelin.

Predator	*Mortality (yr^{-1})*	*percentage*
Cod > 35cm	0.29	26.9
Pisc. SPF	0.14	13.0
G.halibut <=40 cm	0.14	13.0
Whales	0.11	10.2
Harp Seals	0.08	7.4
Cod <= 35 cm	0.07	6.5
Aplaice <=35 cm	0.07	6.5
Aplaice >35 cm	0.04	3.7
Capelin	0.04	3.7
Seabirds	0.03	2.8
Arctic cod	0.02	1.9
Fishing	0.01	0.9
G.halibut >40 cm	0.01	0.9
Flounders	0.01	0.9
Skates	0.01	0.9
S.Dem.Feeders	0.01	0.9
Total	1.08	100.0

Sand lance

The sand lance biomass estimate was based on sand lance trawlable biomass in the 1990s, which was then raised by a catchability of 0.1, based on Edwards (1968). The biomass required to balance the model (1,332,540 t) is 1.3 times that biomass. Given the uncertainty in the original estimate, this is feasible simply by assuming that the catchability was 0.08 rather than 0.1.

A total of 14 groups prey on sand lance. Cod > 35 cm and capelin are the main predators, while both size groups of American plaice play a role, in addition to harp seals, skates and whales (Table 30). The biomass estimated for sand lance is likely to be a good approximation.

Table 30. Composition of predation mortality on sand lance.

Predator	*Mortality (yr^{-1})*	*percentage*
Cod > 35cm	0.26	23.9
Capelin	0.22	20.2
Aplaice >35 cm	0.12	11.0
Harp Seals	0.11	10.1
Aplaice <=35 cm	0.10	9.2
Skates	0.08	7.3
Whales	0.06	5.5
Others	0.14	12.8
Total	1.09	100.0

Arctic Cod

To estimate the biomass of Arctic cod, it was assumed that the catchability of Arctic cod was the same as the catchability of capelin. The biomass estimated in the balanced model is 10 % greater than the original estimate. Given the approximate nature of the biomass estimation, this is an acceptable margin of error.

Harp seals are the main predators of Arctic cod, accounting for over 60 % of the total mortality (Table 31). There is no fishing mortality on this group.

Table 31. Composition of predation mortality on Arctic cod.

Predator	*Mortality (yr^{-1})*	*percentage*
Harp Seals	0.23	60.5
Cod > 35cm	0.05	13.2
G.halibut <=40 cm	0.04	10.5
Cod <= 35 cm	0.02	5.3
S.Dem.Feeders	0.02	5.3
Seabirds	0.01	2.6
Arctic cod	0.01	2.6
Total	0.38	100.0

Piscivorous small pelagic feeders

The biomass of this group increased by over 200 %, to 746,955 t, in the balanced model. This substantial increase is largely driven by the predatory requirements of whales, which account for over 50 % of the predation mortality (Table 32). (Much of this consumption by whales is on squid.) Harp seals and skates are also important predators. As described above, the biomass of short-finned squid was thought to be low during the years of the study, so this high biomass estimate is suspect. Fishing accounts for a mortality of 0.01 yr^{-1}.

Table 32. Composition of predation mortality on piscivorous small pelagic feeders.

Predator	*Mortality (yr^{-1})*	*percentage*
Whales	0.32	56.1
Harp Seals	0.11	19.3
Skates	0.06	10.5
L.Pel.Feeders	0.02	3.5
Others	0.06	10.5
Total	0.57	100.0

Planktivorous small pelagic feeders

The biomass of the planktivorous small pelagic feeders increased by 275 %. The greatest predators on this group are redfish and piscivorous small pelagic feeders (Table 33). The biomass of both these groups increased in the balanced model. The planktivorous small pelagic feeders include myctophids and other mesopelagics and *Gonatus* squid. The biomass of these groups is essentially unknown. The initial estimate above was a "guesstimate", and the current estimate may be valid.

Table 33. Composition of predation mortality on planktivorous small pelagic feeders.

Predator	*Mortality (yr^{-1})*	*percentage*
Redfish	0.26	55.3
Pisc. SPF	0.06	12.8
Harp Seals	0.03	6.4
Whales	0.02	4.3
Hooded Seals	0.02	4.3
G.halibut <=40 cm	0.02	4.3
Others	0.06	12.8
Total	0.47	100.0

Shrimp

The estimated shrimp biomass of 722,205 t for 2J3KLNO is more than 600 % greater than the original estimate, which applied to 2J3K only. It is also greater than the 1996-1997 biomass estimate of 400,000 t for 2J3K (Parsons and Veitch 1998). The main predators of this group are large crustaceans, cod > 35 cm, small demersal feeders and cod ≤ 35 cm, Table 34.

Table 34. Composition of predation mortality on shrimp.

Predator	*Mortality (yr^{-1})*	*percentage*
Large Crustacea	0.53	39.0
Cod > 35cm	0.17	12.5
S.Dem.Feeders	0.14	10.3
Cod <= 35 cm	0.11	8.1
Redfish	0.09	6.6
L.Dem.Feeders	0.09	6.6
Harp Seals	0.08	5.9
Plankt. SPF	0.04	2.9
Others	0.11	8.1
Total	1.36	100.0

Large Crustacea

The large crustacean biomass underwent an enormous increase of over 1800 % to 1,756,260 t in the balancing of the model. This increase is largely driven by skates and cod > 35 cm (Table 35). Cannibalism was reduced to 1 % of the diet, but it still accounts for over 11 % of the total mortality.

The large crustacea are a key group at the lower trophic levels in this system. They directly affect the biomass estimates of the small demersal feeders and shrimp. The biomass estimates for these 2 groups are large, because the initial large crustacea biomass estimate is large. Large crustacea feed on shrimp and small demersal feeders, small demersal feeders feed on shrimp and large crustaceans, and shrimp feed mainly on zooplankton and detritus. A trophic triangle exists among these groups and the estimate of large crustacea biomass impacts on the other 2 groups.

Table 35. Composition of predation mortality on large crustacea.

Predator	*Mortality* (yr^{-1})	*percentage*
Skates	0.13	37.1
Cod > 35cm	0.09	25.7
Large Crustacea	0.04	11.4
S.Dem.Feeders	0.03	8.6
Aplaice >35 cm	0.02	5.7
Aplaice <=35 cm	0.02	5.7
Cod <= 35 cm	0.01	2.9
L.Dem.Feeders	0.01	2.9
Total	0.35	100.0

Large Zooplankton and Small Zooplankton

The biomass of the large zooplankton is increased by 22 % from the original estimate and the biomass of the large zooplankton is increased by 55 %. Both of these estimates are on the high side. Capelin and cannibalism are the main sources of mortality for large zooplankton, accounting for 65 % of the mortality. Almost all (78 %) of the predation mortality on the small zooplankton, is by the large zooplankton.

Model 2: Further Improvements to the Model

The balanced model described above is not completely consistent with what is known or surmised about the ecosystem. There are two areas which are of particular concern; the impact of skates and an apparent trophic triangle of large crustacea, small demersal feeders and shrimp.

The impact of skates

The mortality analysis placed skates as the fifth most important natural predator of vertebrates. They have a high impact on cod ≤ 35 cm, redfish, small demersal feeders, sand lance, piscivorous small pelagic feeders and large crustaceans. They have not previously been considered as major predators in the system, and the results here may be in error. In order to examine this possibility, the input parameters and the sensitivity of the model output were re-examined.

The biomass estimate was derived from the Engels trawlable biomass estimate, raised by a factor of 2.2, to a Campelen equivalent. However, this raising factor may be too high. The mean size of skates has declined since the 1980s (Kulka *et al.* 1996) and the Campelen gear catches more small fish than the Engels gear. Thus, in the 1990s, when the Engels:Campelen ratio was estimated (see above), the catch consisted of a greater proportion of small fish, which the Campelen gear caught efficiently, while the Engels gear did not. This would artificially raise the ratio between the two gears, and would not represent the situation in the mid-1980s. So, instead of raising the skate biomass to a Campelen equivalent, it is assumed that the Engels biomass estimate is a better indicator of skate biomass in the mid-1980s. In order to allow for some error, a 10 % error term was used. Thus, the biomass range was 104,553 - 127,787 t. The high end of the range was used below. This reduction in the biomass of the skates produced biomass reductions in the groups noted above, ranging from 5 % for sand lance, 10 % for cod ≤ 23 cm, to 20 % for the large crustacea.

The skate P/B ratio and Q/B ratio were left unchanged since there was no rationale for altering them. Sensitivity to a change in the Q/B ratio was the same as sensitivity to a change in skate biomass.

The skate diet was adapted from the aggregate diet for thorny skate (see Appendix 2, Table 8 and Templeman 1982). Piscivory in this diet was reduced by 20 %, and the difference attributed to the invertebrate groups. However, predation on the large crustaceans in particular was very high. In order to reduce this, the 20 % originally due to piscivory and distributed to invertebrate groups, was redistributed to the polychaetes and amphipods (large zooplankton) only. Both groups are prevalent in the diet of smaller skates (Templeman 1982).

The large crustacea - small demersal feeders - shrimp trophic triangle

The model estimates of biomass for the large crustacea, small demersal feeders and shrimp were very high. These groups form a trophic triangle: large crustacea and small demersal feeders prey on each other, where predation by large crustacea is much stronger than predation by small demersal feeders; shrimp are prey to both species. This mutual predation drives the biomass of both groups. The consequent high consumption of shrimp drives the biomass of shrimp upwards.

The diet of the large crustacea was re-examined. In the original diet (Table 2b), small demersal feeders composed 5 % of the crab diet. It was noted that the diets from which this was derived (Wieczorek and Hooper 1995; Miller and O'Keefe 1981) were expressed in percentage frequency of occurrence, whereas here percentage weight is used. The diet was re-estimated using a different rationale. The fish that were present in the diet have been re-classified as detritus, on the assumption that these fish were scavenged, see Appendix 2, Table 18. In addition, the P/B was raised from 0.38 to 0.45 yr^{-1}.

In addition, the consumption to biomass ratio of cod > 35 cm was reduced from the middle of the input range to the lower end of the input range, that is, from 3.24 to 2.2 yr^{-1}.

The resultant changes in biomass for large crustacea, small demersal feeders and shrimp are shown in Table 36. The biomass estimates are reduced by more than 50 % for large crustacea and small demersal feeders.

The difference between the biomass estimates from Models 1 and 2 and the unbalanced model are shown in Figure 7. In addition to the large reductions in biomass estimates for the large crustacea, small demersal feeders and shrimp, the estimated biomass of several other species were also reduced, making Model 2 a better fit to the original parameters. These species include cod ≤ 35 cm, Greenland halibut ≤ 40 cm, flounders, redfish, sand lance, Arctic cod, piscivorous small pelagic feeders, planktivorous small pelagic feeders, large zooplankton and small zooplankton.

Table 36. Comparison of biomass before and after changes to the large crustacea and skate groups.

	Before changes $t \cdot km^{-2}$	*After changes* $t \cdot km^{-2}$
Large crustacea	3.548	1.732
Small demersal feeders	5.060	2.380
Shrimp	1.459	0.816

Differences also resulted in the predator spectrum of several of the prey groups, Table 37 and Tables 24 to 35. The predatory impact of cod > 35 cm, skates, large crustacea and small demersal feeders was reduced on all prey groups. For the small demersal feeders, large crustacea and shrimp, predation by skates and large crustacea was reduced while the role of other predators such as harp seals became more important. In addition, for cod ≤ 35 cm, harp seals became the main predator. This is due to the reduction in the consumption of cod > 35 cm. Large demersal feeders have a predatory impact on skates, whereas when the skate biomass was larger, this predation was negligible.

For many groups, the total mortality remained the same in Models 1 and 2. However, there were a few exceptions. Predation mortality on the large crustacea increased overall. This is due to their decreased biomass and increased predation by all predators except small demersal feeders and skates. The predation mortality on capelin and the other invertebrate groups (echinoderms, molluscs, polychaetes and other benthic invertebrates) decreased. Predation mortality on capelin decreased due to decreased predation by cod > 35cm, cod ≤ 35 cm, Greenland halibut > 40 cm and skates. The predation mortality on the other invertebrate groups decreased due to decreased predation by small demersal feeders and large crustacea

Mortality

The distribution of predation mortality in Model 2 is shown in Figure 8. The top chart (Figure 8a) gives the distribution of predation mortality amongst the vertebrate predators on all the prey groups. Compared to the unbalanced model, the same key predators are present here, that is, cod > 35 cm, harp seals, skates and capelin, but they appear in a different order. Capelin now accounts for the greatest amount of predation mortality, followed by harp seals and cod > 35 cm. Other groups such as sand lance, large crustacea, and small demersal feeders have become more important predators, whilst the level of predation imposed by the skates has decreased.

Compared to Figure 5a, a greater number of groups contribute to the predation mortality. For example, in Figure 5a, the top 50 % is comprised of only 3 groups, whereas in Figure 8a it is composed of 5 groups (excluding fishing). The top 75 % is composed of 6 groups in Figure 5a and 12 groups in Figure 8a. Thus the balanced model is less dominated by a small number of predators.

The distribution of predators on vertebrate prey or fish prey is shown in Figure 8b. Harp seals are now the top predators in the system, followed by fishing. After fishing, cod > 35 cm, whales, hooded seals and Greenland halibut > 40 cm are the greatest predators of fish.

Table 37. Predator mortality on individual prey groups (yr^{-1}): Model 2.

PREDATORS	*PREY*											
	6 Cod <= 35 cm	*8 G.halibut <=40cm*	*11 Flounders*	*13 Redfish*	*15 S.Dem. Feeders*	*17 Sand lance*	*20 Pisc. SPF*	*21 Plankt. SPF*	*22 Shrimp*	*23 LC*	*28 LZP*	*29 SZP*
1. Whales	0.13				0.04	0.07	0.34	0.03			0.02	0.01
2. Harp Seals	0.40	0.31	0.15	0.01	0.06	0.13	0.12	0.04	0.14		0	
3. Hooded Seals		0.27	0.09	0.01	0.02		0.01	0.02				
4. Seabirds	0.01				0	0.01	0.01	0.01	0		0	0
5. Cod > 35cm	0.29	0.06	0	0.03	0.08	0.20	0	0.01	0.2	0.12	0.01	
6. Cod <= 35 cm	0.04	0.01			0.02	0.02	0.01	0.01	0.16	0.02	0.02	
7. G.halibut >40 cm	0.14	0.14	0	0.08	0.02		0	0	0.01		0	
8. G.halibut <=40 cm	0.07	0.02			0.01		0.01	0.02	0.06		0	
9. Aplaice >35 cm		0			0.01	0.14			0.01	0.05	0	
10. Aplaice <=35 cm	0.04	0.01	0.02	0	0.03	0.12			0.05	0.04	0.01	
11. Flounders					0.01	0.04			0.03		0.01	
12. Skates	0.13	0	0	0.04	0.03	0.05	0.03	0	0.01	0.09	0	0
13. Redfish	0.02			0.01	0	0.01		0.25	0.14		0.08	0.02
14. L.Dem.Feeders	0.06		0.01	0.01	0.03	0.02	0	0.02	0.16	0.02	0.01	0
15. S.Dem.Feeders					0.02	0.02	0.01	0	0.12	0.03	0.01	0.01
16. Capelin						0.25					1.22	1.02
17. Sand lance											0.30	0.38
18. Arctic cod											0.23	0.08
19. L.Pel.Feeders	0			0	0	0	0.02	0.01	0		0	0
20. Pisc. SPF	0.17					0.01		0.07	0.02		0.02	0
21. Plankt. SPF									0.06		0.27	0.15
22. Shrimp											0.05	0.06
23. Large Crustacea									0.19	0.04	0.01	0
28. L.Zooplankton											0.98	6.26
TOTAL	1.50	0.82	0.27	0.19	0.38	1.09	0.56	0.49	1.36	0.41	3.25	7.99

Fishing versus predation

In terms of overall predation, the fishery is the fourth top predator (excluding invertebrate predators). For predation on vertebrate prey only, the fishery is the second top predator; harp seals take a greater biomass of fish from the system. Figure 9 illustrates the distribution of fishing mortality across the prey groups and compares this to the predation mortality for each group. The two different mortalities are distributed to the left and the right of the plot. The fishery focuses on the large fish groups and the predators on the smaller fish groups. Hence, fishing removes more spawning biomass but less pre-recruits and immature fish than the natural predators.

The fishery is the only predator on harp seals[2] (not shown) and American plaice > 35 cm. Fishing greatly exceeds predation mortality on cod > 35 cm, and exceeds predation mortality on skates, large pelagic feeders and Greenland halibut > 40 cm. For American plaice ≤ 35 cm, flounders, redfish, large demersal feeders, capelin and piscivorous small pelagic feeders, predation mortality is greater than fishing mortality. There is some exploitation of planktivorous small pelagic feeders, shrimp and large crustacea, but the fishing mortality is low due to the large biomass estimated for these groups. Note that no predators of seabirds were included in the model, and catch included various types of anthropogenic mortality, such as hunting or oil discharges at sea. For these reasons, they are not included in this comparison.

These results indicate that the fishery has a large impact on several species. It includes the key commercial species such as cod > 35 cm , Greenland halibut > 40 cm and American plaice > 35 cm, but also other species such as skates, large pelagic feeders and redfish. However, there are also many species for which the harp seals and cod > 35 cm impose higher mortality. These include cod ≤ 35 cm, Greenland halibut ≤ 40 cm, American plaice ≤ 35 cm, flounders, small demersal feeders, capelin, sand lance, Arctic cod, small pelagic feeders, shrimps and large crustacea (Figure 9). Clearly, fishing, harp seals and cod > 35 cm are major predators in this system. However, for most of the species that are fished, the fishery takes the lion's share.

Discussion

The results described above indicate a system for which our information is uncertain. As a consequence, there are several, if not many, possible versions of the model. Three are described here: an unbalanced model; a model that is balanced by allowing the model to estimate the biomass of some prey groups (Model 1); and a model in which further modifications are made to the skates and large crustacea in Model 1 (Model 2).

The uncertainty over the input parameters for some of the groups at the lower trophic levels has been discussed above. However, there are also several areas of uncertainty for groups at higher trophic levels. These uncertainties are transmitted down the food web, since all production and losses must be balanced for each group. A high consumption at the top of the food web requires high production at all lower levels. The results of a sensitivity analysis indicate that the model is sensitive to some of the groups.

Sensitivity Analysis

Sensitivity analyses of Models 1 and 2, where the basic input parameters B, P/B, Q/B and EE were varied between –50 % and +50 %, indicate that for many groups, sensitivity is relatively low (see Appendix 3, Tables 1 and 2). A 50 % change in the input parameters of some groups effected a response of less than 15 % in the estimated parameters of other groups. These groups include cod ≤ 35 cm, Greenland halibut > 40 cm, Greenland halibut ≤ 40 cm, American plaice > 35 cm, American plaice ≤ 35 cm, redfish, large demersal feeders, Arctic cod, piscivorous small pelagic feeders, and planktivorous small pelagic feeders. The model is insensitive to several groups, such as the seabirds, large pelagic feeders, shrimp, echinoderms, molluscs, polychaetes and other benthic invertebrates. The linkages between groups are shown graphically in the foodweb in Figure 10.

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[2] Note that marine mammals are also caught by fishing gear as by-catch, for example, seals are caught in lumpfish gear and whales in gillnets and traps (B. Montevecchi, *pers. comm.*).

The model is most sensitive to the groups at the top of the food web and at the bottom of the food web. For example, a 50 % decrease in the biomass of the whales resulted in a 35 % decrease in the estimated biomass of the large demersal feeders and piscivorous small pelagic feeders. Arctic cod show a similar sensitivity to the harp seal biomass. The estimated biomass of the flounders and Greenland halibut ≤ 40 cm decreased by 20 %, and cod ≤ 35 cm and large pelagic feeders decreased by 15 %, in response to a decrease of 50 % in the biomass of harp seals. Several groups are sensitive to the biomass of cod > 35 cm: American plaice ≤ 35 cm is the most sensitive, then large crustacea, small demersal feeders, capelin, sand lance and molluscs, shrimp and cod ≤ 35 cm.

The greatest sensitivities, however, are to the large crustacea and the large zooplankton. A 50 % reduction in the P/B ratio of the large crustacea results in: a 63 % increase in the estimated biomass of small demersal feeders and shrimp; a 100% increase in the estimated EE of the echinoderms and molluscs; and a 75 % increase in the estimated EE of polychaetes (Figure 11). Thus the change effected is greater than the change to the input parameter. Sensitivity to the large crustacea was reduced in Model 2 as a result of the reduction of the large crustacea biomass. Since the small demersal feeders were no longer included as live fish in the large crustacea diet, they are no longer sensitive to the large crustacea. The sensitivity of the other groups above was reduced to between 50 and 70 % increases in their estimated parameters.

Sensitivity to the large zooplankton was considerably greater. The biomass of the small zooplankton and the EE of the phytoplankton increased by 200 % when the P/B of large zooplankton was reduced by 50 %. This was the same for Models 1 and 2.

In general, there was less sensitivity in Model 2 than Model 1. This is due to the decreased biomass and Q/B ratios of some of the predator groups. A few prey groups whose biomass was reduced, such as the shrimp, were more sensitive. Unfortunately, the models were most sensitive to one of the groups that we know least about, that is, the large crustacea. The input parameters for this group were changed in the balancing of the models. However, these parameters are still highly uncertain and impact on several groups. Fortunately, the model is not sensitive to the groups on which they impact, that is, shrimp, echinoderms, molluscs, polychaetes and other benthic invertebrates. However, if the assumptions made about the small demersal feeders in the diet of the large crustacea are erroneous, this ceases to be true. Shrimp and large crustacea are both sensitive to the small demersal feeders input parameters. The models are even more sensitive to the large zooplankton. However this only affects groups to which the model is not sensitive, that is, the small zooplankton and the phytoplankton. Essentially, neither model simulates these lowest trophic levels well; they are highly aggregated and serve as producers for the higher trophic levels. However, if for example there was greater certainty about the biomass of the large zooplankton, then this biomass could act as a limiting factor for the productivity of higher trophic levels.

Uncertainties in the data

Whales

The input data for the whales were broad estimates. Biomass was estimated from numbers, generally rounded to the nearest 1,000, and multiplied by mean weight. However, it was noted that the consumption of squid by whales requires a high biomass estimate of the piscivorous small pelagic feeders. The biomass of short-finned squid was not considered to be this high.

The main species of whale that consume piscivorous small pelagics are sperm whales and pilot whales (potheads). The biomass and diet compositions of both species are poorly known, yet they have a large influence on the model estimates. Their consumption requirements of squid drive the biomass of the piscivorous small pelagic feeders estimated to meet this consumption demand. This, in turn, increases the predation mortality on cod ≤ 35 cm and therefore their biomass. Pilot whales in Newfoundland are described as following the squid to inshore waters where squid is their main food (Sergeant 1962). In years when there are few squid, there are few pilot whales. Squid have not been abundant in Newfoundland waters since the late 1970s and early 1980s (Black *et al.* 1987; Montevecchi 1993). J. Lien (*pers. comm.*) has not observed any pilot whales in Newfoundland waters in the past 3 years and it is thought that they have moved to the Gulf of St. Lawrence. The numbers of sperm whale are not well known.

Thus, it is conceivable that the whale biomass is lower than estimated, that the piscivorous small pelagic feeders component of the whale diet composition is lower than described, and that the biomass of the piscivorous small pelagic feeders is lower than estimated above.

Harp Seal

There are a number of areas of uncertainty surrounding the parameter estimates of the harp seals (Shelton *et al.* 1997; Warren *et al.* 1997). Uncertainties include residency times, population estimates, diet data and energy requirements (G. Stenson, *pers. comm*). The biomass of the harp seals is estimated from the model of Shelton *et al.* (1996a). Warren *et al.* (1997) analysed uncertainty in population size with respect to pup production from survey estimates. Their estimated 95 % confidence range allows for a 10 % variation in the population estimate of 91,184 t. If the uncertainty over residency time, the proportion of seals in the Front herd, the Gulf herd and those which remain in the Arctic are included, the range of uncertainty in the estimate may extend to 20 %. Shelton *et al.* (1997) found that estimates of cod consumption by harp seals had CVs as high as 35 %.

There is also uncertainty over the diet composition. The composite diet is a combined inshore and offshore diet. It is assumed that 45 % of the harp seals are inshore and 55 % are offshore, and that they are randomly distributed across the area. It is assumed that the inshore diet is representative of seals eating within 100 km of the shoreline (G. Stenson, *pers. comm.*). However, these inshore:offshore ratios may be incorrect. Additionally, the data for the offshore diet for the 1980s are poor, and it is assumed that the diet is the same as during the 1990s. Even so, the offshore diet data for the 1990s are poorer than the inshore diet data and it is feasible that the greater part of the diet occurs offshore (G. Stenson, *pers. comm.*). If this were the case, consumption of cod ≤ 35 cm and Arctic cod would decrease and consumption of capelin and sand lance would increase.

There are similar uncertainties for hooded seals.

American plaice

The estimated biomass of American plaice is surprisingly high when compared to the biomass of cod (869,168 t and 1,044,656 t respectively). The American plaice biomass was estimated from Campelen converted data, using numbers at length and a length-weight relationship, then extrapolating from 3LNO to find the biomass for 2J3K. The 3LNO biomass estimate is in agreement with the DFO working group estimate (W. Brodie, *pers. comm*). In contrast, the biomass of cod was taken from SPAs. It is possible that biomass estimates from Campelen trawl surveys exceed those from SPAs for both American plaice and cod.

In all models, the EE of American plaice of both size classes is low. This is caused by low mortality on both adults and juveniles. The predation mortality on both American plaice > 35 cm and American plaice ≤ 35 cm is low compared to other groups in the system. This may be due to the lack of definition of American plaice in the stomach samples used to estimate diets. Flatfish are difficult to identify and thus a large proportion of flatfish is "unidentified". In the construction of the diets, some of these unidentified flatfish may have been American plaice that were mistakenly assigned to large demersal feeders (G. Lilly, *pers. comm.*).

There is also an anomaly in the feeding habits of American plaice. Fish are more important in the diet of the small size group than in that of the large size group. Fish as a percentage of the diet is 48.7 % for the small American plaice and 47.8 % for the large size. Moreover, the smaller size group has a greater diversity of fish in its diet (cod ≤ 35 cm, Greenland halibut ≤ 40 cm, American plaice ≤ 35 cm, flounders, redfish, small demersal feeders, capelin, sand lance and Arctic cod) than the large size group (Greenland halibut ≤ 40 cm, American plaice ≤ 35 cm, small demersal feeders, capelin, sand lance and Arctic cod).

Small demersal feeders, large crustacea, large zooplankton

In the balancing of Models 1 and 2, the parameters of the small demersal feeders, large crustacea and large zooplankton were changed from the original estimates to accommodate the apparent consumption demands of higher trophic levels. Again, this highlights how little we know about the lower trophic levels. Unfortunately, the model is sensitive to all these groups.

Existing information on the small demersal feeders and the large crustacea is scant. The biomass estimated by the model is much larger than the biomass estimated from trawl survey and other data. In order to increase the credibility of these models, it is important to get better data for these groups.

In the case of the large zooplankton, only the small zooplankton and phytoplankton are directly sensitive to the input parameters. However, as discussed further below, the large zooplankton form the base of the forage production. If there were better estimates of large zooplankton, small zooplankton and phytoplankton biomass for the mid 1980s, these data could constrain the allowable productivity at higher trophic levels.

Additional comments on diet

Weaknesses in diet data have been noted in many sections of this paper. Additional comments are warranted regarding small juvenile fish in the diets of predators and the degree to which an exercise such as this can provide insightful analysis of the contribution of various predators to the mortality of a commercially important top predator such as Atlantic cod.

There are problems with how small (say < 6-7 cm) fish are included within the model, both as predators and as prey. For most fish species, their role as predators while they are small (< 6-7 cm) has not been included explicitly in the present model. Their role as prey has not been treated equally for all species. For example, the model results show considerable predation by capelin on sand lance and capelin (cannibalism). This seems at first somewhat surprising, because capelin is considered to be planktivorous. The information regarding predation on sand lance and capelin comes from careful observations of stomach contents of capelin at sea in the spring (Gerasimova 1994). If there were similar observations of the diet of other species at the time when juveniles of potential prey are in the water column or just settling out of the water column, then more predation on small (< 6-7 cm) individuals of many species might be recognized. For example, studies in the Barents Sea have pointed to the importance of predation by herring on small capelin. Such predation may occur unrecognized in Newfoundland waters because there have been no careful studies of herring stomach contents during the period between the hatching of capelin and their flushing out of inshore waters.

At the time of writing of this paper, there is considerable interest in the contribution of various predators, most notably harp seals, to the mortality of Atlantic cod. The present model provides estimates of the contributions by various predators or groups of predators, but it must be clear that the diet information for all of these predators is inadequate for obtaining accurate estimates of their consumption of minor prey. For example, the information on predation by whales comes mainly from reports of cod in the diet of pilot whales, and yet the actual proportion of cod in the diet of pilot whales is not known. In addition, pilot whales may not have been very abundant in Newfoundland waters in 1985-1987 because there were very few short-finned squid (see section on Whales above). On the other hand, minke whales are reported to prey on Atlantic cod in the Barents Sea, but there is no recent information on the diet of minke whales in Newfoundland waters. After the analyses reported in this paper were completed, the estimate of the quantity of Atlantic cod consumed by harp seals was considerably reduced (Lilly *et al.* 1999), illustrating the uncertainty involved in these calculations. Predation on Atlantic cod by skates remains very uncertain because diet data for skates are sparse and perhaps unrepresentative. The importance of cannibalism in Atlantic cod needs to be calculated more carefully. It has been suggested that Arctic cod might eat small Atlantic cod. Although this has not yet been observed, it must be noted that the stomach contents of Arctic cod have not been examined during the late summer and early autumn when pelagic juvenile Atlantic cod would be in the water column. The information on predation by short-finned squid on Atlantic cod came from very few sites and there is no quantitative information on the biomass of squid entering Newfoundland waters each year. For each of the various predators discussed above, Atlantic cod is a minor component of the diet, and an extensive and intensive stomach sampling program would be required to obtain accurate estimates of the number/quantity of Atlantic cod consumed.

There is also considerable uncertainty about how the model might take into account predation on eggs and larvae. For example, eggs and larvae of Atlantic cod could be preyed upon by planktivorous fish (capelin, herring, Arctic cod) and various groups of invertebrates, including jellyfish, euphausiids, shrimp and crab larvae. Such predation is not included in the models described in this paper. The consequence of excluding such predation is not known but likely to be small as long as one is interested in biomass flows. However, such links between species and species groups might be very important if the model outputs are to be used as input to dynamic models.

Network Flow Analysis

The biomass flows between Ecopath groups in Model 2 are shown in Figure 10. The trophic levels are given in Table 23, and indicated on the y-axis of the figure. Hooded seals are at the top of the food web, reflecting the high proportion of fish such as Greenland halibut ≤ 40 cm and cod ≤ 35 cm in the diet. There are several other groups (including Greenland halibut, harp seals, cod and skates) with a trophic level higher than four, reflecting the high number of top predators in this system.

This high level of predation is supported by a large pelagic forage base, which includes capelin, sand lance, Arctic cod, and planktivorous small pelagic feeders. Large zooplankton and small zooplankton form the basis of this forage network. The main production by large zooplankton and small zooplankton is channelled through capelin. Capelin are thus the critical converter of energy produced at lower trophic levels to a form available to the higher trophic levels. The important role of capelin in the food web is shown in Figure 12. To fulfil this role, capelin require almost 11% of the primary production in the system.

As shown in Figure 10, there are many linkages in the model. The pelagic side of the food web dominates the system in terms of energy flow. For example, around 80 % of the energy required by harp seals and cod > 35 cm is derived from the pelagic side of the foodweb. Harp seals require 5% of primary production and cod > 35 cm require 4.6 % of primary production. However, little empirical data are available for any of the pelagic species that link the zooplankton to the top predators of the system.

Benthic productivity is even less well understood. As modelled here, less than 1% of the energy consumed by echinoderms and molluscs is transferred to the next trophic level. This is an extremely low transfer efficiency. It is very likely that most of the interactions at this level are lost in the aggregation process and are thus not well modelled. The benthic invertebrate groups are at a trophic level of 2, and their consumers are all at trophic level 3 or higher. A more realistic model would include consumers that spanned these two trophic levels.

Concluding remarks

The Ecopath model presented here provides a summary of our current knowledge of the biomass, consumption, production, food web and trophic flows in the ecosystem exploited by the Newfoundland fishery in divisions 2J3KLNO. The study confirms some of our knowledge, such as the important forage role played by capelin and the dominance of predators such as harp seals and cod. It suggests that harp seals and cod > 35 cm are the two major predators of cod ≤ 35 cm.

The model also highlights many of the uncertainties in our knowledge. Unfortunately, these uncertainties extend over all trophic levels and many of the constituent groups of the models, including those that are regularly surveyed and assessed. It was necessary to make several assumptions to balance the model. For some model estimates, such as the biomass of the small demersal feeders, there is little known to either substantiate or discredit their magnitude. The sensitivity analysis indicated that the model was not very sensitive to the biomass of the small demersal feeders. However, if the biomass of this group was reduced to the original estimate, the model would not be balanced. Thus the estimated biomass is critical to the model, as parameterised.

The biomasses of several other groups, such as juveniles of commercial species, piscivorous small pelagic feeders, planktivorous small pelagic feeders, shrimp, and large crustacea, were also raised during the balancing process. Thus, the model indicates a greater biomass at lower trophic levels than has been estimated to date. This result has been found in other ecosystem modelling studies. For example, Welch *et al.* (1992) modelled the Lancaster Sound with a bioenergetics model. Their model predicted a greater biomass of Arctic cod than estimated by acoustic and trawl surveys. Earlier work by Jones (1984) focussed on primary and secondary producers in the North Sea and Georges Bank and showed that with more than one to two pathways from prey to predator, there was insufficient production to sustain the predator.

There are two major implications of this study. The first is that we know little about productivity at lower trophic levels. Since there is continued debate over whether different species and trophic levels are food limited or predator limited, knowledge of the productivity of lower trophic levels is clearly important. Secondly, this study demonstrates the utility of studying top predators to estimate the system energy flows required to sustain those top predators. We cannot begin to understand the ecosystem effects of fishing until we understand the nature of interactions between different species or groups, at all levels of the food web.

Recommendations

There are two main areas where better data are required: diet and biomass estimation.

Uncertainty over diet data

For many of the groups in the model, empirical diet data from the model area were sparse or non-existent. Where data did not exist information was taken from the literature. However, even for groups with good diet data, numerous shortcomings were noted. The following recommendations are made for new diet studies:

Sampling should include the full size spectrum of each predator and extend over the predator's full geographic distribution with sufficient temporal coverage to ensure that all major seasonal changes in diet are represented. Stomach content examinations should be conducted at a taxonomic level sufficient to accommodate at least the finest level of aggregation desired in the models and should include information on the size, number and weight of the prey. Additional information that might be helpful includes state of digestion of the prey. During calculation of the average diet composition, samples should be weighted by the predator population numbers at length. Variation in digestion rate associated with factors such as temperature, type and size of prey, and degree of stomach fullness should be taken into account.

Biomass estimation

Biomass estimates serve to scale the model but the biomass estimates are poor for many groups. This is especially so at lower trophic levels, but also occurs at higher levels such as the whales, whose biomass estimates are crude approximations derived from the products of estimated numbers and mean weights. The models would be more robust if more confidence could be placed in the biomass estimates.

As a final word, we wish to note that the process of constructing models such as these is essentially open-ended. The data available for inputs are constantly being added to and revised. The models presented here should be considered a first step. We invite others to critique the model structure, the input data and the assumptions, so that the models can be improved during subsequent exercises. The data used in the current models are available from the authors upon request.

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References

Ajiad, A.M., and T.Y. Pushchaeva (1992) The daily feeding dynamics in various length groups of the Barents Sea capelin. In: Bogstad, B. and S. Tjelmeland (Eds.) Interrelations between fish populations in the Barents Sea. Proc. of the Fifth PINRO/IMR Symposium, Murmansk, 12.-16. August 1991 (Also published as ICES CM 1991/H:16).

Albikovskaya, L.K. (1983) Feeding characteristics of wolffishes in the Labrador-Newfoundland region. NAFO Sci. Coun. Studies 6: 35-38.

Alldredge, A. (1984) The quantitative significance of gelatinous zooplankton as pelagic consumers. In: M.J. Fasham (ed.) Flows of energy and materials in marine ecosystems: theory and practice. Plemum Press, New York. pp. 407-453.

Allen, K.R. (1971) Relation between production and biomass . J. Fish. Res. Bd. Canada, 28(10):1573-1581.

Anderson, J.T. and E.L. Dalley (1997) The nekton of the coastal and shelf waters of Newfoundland. DFO CSAS Res. Doc. 97/124.

Anon. (1987) NAFO Statistical Bulletin. Fisheries Statistics for 1985. Vol. 35, 321 p.

Anon. (1989) NAFO Statistical Bulletin. Fisheries Statistics for 1986. Vol. 36, 304 p.

Anon. (1990) NAFO Statistical Bulletin. Fisheries Statistics for 1987. Vol. 37, 295 p.

Anon (1991a) Report of the International Whaling Commission, 41, pp.138.

Anon (1998) Report of the joint ICES/NAFO working group on Harp and Hooded Seals. ICES CM 1998/Assess:3.

Barlow, J and P.J. Clapham (1997) A new birth-interval approach to estimating demographic parameters of humpback whales. Ecology, vol. 78 (2): 535-546.

Barrie, J. (1979) Diversity of marine benthic communities from nearshore environments on the Labrador and Newfoundland coasts. M.Sc. thesis, Memorial University of Newfoundland, St. Johns, Newfoundland. 113 p.

Barrie, J.V and M.B.Collins (1989) Sediment transport on the shelf margin of the Grand Banks of Newfoundland. Atlantic Geology 25: 173-179.

Barrie, J.D., B.A. Bennet, S.M. Browne and A.J. Moir (1980) Nearshore studies in the Makkovik and Cartwright region. Offshore Labrador biological studies, 1979: benthos. 158 p.

Barrie, J.V., C.F.M. Lewis, G.B. Fader and L.H. King (1984) Seabed processes on the northeastern Grand Banks of Newfoundland; modern reworking of relict sediments. Marine Geology 57: 209-227.

Black, G.A.P.; T.W. Rowell and E.G. Dawe (1987) Atlas of the biology and distribution of the squids *Illex illecebrosus* and *Loligo pealei* in the Northwest Atlantic. Can. Spec. Publ. Fish. Aquat. Sci.,100: 68 p.

Bowering, W.R. (1983) Age, growth and sexual maturity of Greenland halibut, *Reinhardtius hippoglossoides* (Walbaum), in the Canadian northwest Atlantic. Fish. Bull. 81: 599-611.

Bowering, W.R. (1997) A review of the status of witch flounder in Divisions 2J3KL. NAFO SCR Doc. 97/61, 15 p.

Bowering, W.R. (1998) Changes in distribution and trends in stock size of the witch flounder resource in Divisions 2J, 3K and 3L. NAFO SCR Doc. 98/64, 16 p.

Bowering, W.R. and D.E. Stansbury (1984) Regressions of weight on length for Greenland halibut, *Reinhardtius hippoglossoides*, from Canadian waters of the northwest Atlantic. J. Northw. Atl. Fish. Sci.,5: 107-108.

Bowering, W.R. and W.B. Brodie (1988) A review of the status of the Greenland halibut resources in NAFO subarea 2 and Divisions 3K and 3L. NAFO SCR Doc. 88/69.

Bowering, W.R., and G.R. Lilly (1992) Greenland halibut (*Reinhardtius hippoglossoides*) off southern Labrador and northeastern Newfoundland (northwest Atlantic) feed primarily on capelin (*Mallotus villosus*). Netherlands J. Sea Res. 29: 211-222.

Bowering, W.R., and W.B. Brodie (1995) Greenland halibut (*Reinhardtius hippoglossoides*). A review of the dynamics of its distribution and fisheries off eastern Canada and Greenland, p. 113-160. In A.G. Hopper (ed.) Deep-water fisheries of the North Atlantic Oceanic Slope. Kluwer Academic Publishers.

Bowering, W.R. and D. Orr (1997) Distribution and abundance of witch flounder in NAFO Divisions 3NO. NAFO SCR Doc. 97/65, 20 p.

Bradstreet, M.S.W, K.J. Finley, A.D. Sekerak, W.B. Griffiths, C.R. Evans, M.F. Fabijan and H.E. Stallard (1986) Aspects of the biology of Arctic cod (*Boreogadus saida*) and its importance in Arctic marine food chains. Can. Tech. Rep. Fish. Aquat. Sci. 1491, 193 p.

Braham, H.W. (1984) The status of endangered whales: An overview. Mar. Fish. Rev. 46(4): 2-6.

Brey, T. (1995) Empirische untersuchungen zur populationsdynamik makrobenthischer evertebraten. Habilitationsschrift, Universität Bremen, 170 p.

Brodie, W.B. (1985) An assessment update of the American plaice stock in NAFO Divisions 3LNO. NAFO SCR Doc. 85/51, 28 p.

Brodie, W.B. (1986) An assessment of the American plaice stock on the Grand Bank (NAFO Divisions 3LNO) NAFO SCR Doc. 86/41

Brodie, W.B. (1987) American plaice in Divisions 3LNO. NAFO SCR Doc. 87/40.

Brodie, W.B. (1988) An assessment of the American plaice stock in Divisions 3LNO. NAFO SCR Doc. 88/37.

Brodie, W.B. (1991) An assessment of Greenland halibut in SA2 and Divisions 3KL. NAFO SCR Doc., 91/88.

Brodie, W.B., D.Power and W.R. Bowering (1993) An assessment of the American plaice stock in NAFO Subarea 2 + Div. 3K. DFO Atlantic Fisheries Res. Doc. 93/23.

Brodie, W.B., W.R. Bowering, D. Power and D. Orr (1997) An assessment of Greenland halibut in NAFO subarea 2 and divisions 3KLMNO, NAFO SCR Doc. 97/52, 37 p.

Buzulutskaya. (1983) Feeding of ocean pout (*Macrozoarces americanus*) in the Northwest Atlantic. NAFO SCR Doc. 83/76, Serial No. N742. 9 p.

Cairns, D.K., W.A Montevecchi, V.L. Birt-Friesen, and S.A. Macko (1990) Energy expenditures, activity budgets, and prey harvest of breeding common murres. Studies in Avian Biology 14: 84-92.

Cairns, D.K., W.A. Montevecchi and W.Threlfall (1989) Researcher's Guide to the Seabird Colonies of Newfoundland. Memorial University of Newfoundland Occasional Papers in Biology 14: 34 p.

Carscadden, J. and B.S. Nakashima (1997) Abundance and changes in distribution, biology and behaviour of capelin in response to cooler waters of the 1990s. In: Proceedings of Forage Fish in Marine Ecosystems. Alaska Sea Grant Program. pp. 457 - 468.

Castonguay, M. and F. Grégoire. (1989) Le maquereau bleu (*Scomber scombrus* Linné) du nord-ouest de l'Atlantique, sous-régions 2 à 6 de l'OPANO: évaluation du stock en

1988 CAFSAC Res. Doc. 89/39.

Chabot, D., G.B. Stenson and N.B. Cadigan (1996) Short and long-term fluctuations in the size and condition of harp seal (*Phoca groenlandica*), in the Northwest Atlantic. NAFO Sci. Coun. Studies, 26: 15-32.

Chan, M., and J. Carscadden (1976) The food and feeding of capelin (*Mallotus villosus*) in the Labrador area during autumn 1973. ICNAF Res. Doc. 76/20, Serial No. 3800. 5 p.

Christensen, V. (1995) A model of trophic interactions in the North Sea in 1981, the Year of the Stomach. Dana 11: 1-28.

Christensen, V. and D. Pauly (1992) A guide to the ECOPATH II software system (Version 2.1) ICLARM Software 6, 72 pp. ICLARM, Manila, Philippines.

Christensen, V. and D. Pauly (eds.) (1993) Trophic models of aquatic ecosystems. ICLARM Conf. Proc. 26, 390p.

Chumakov, A.K. and S.G. Podrazhanskaya (1986) Feeding of Greenland halibut (*Reinhardtius hippoglossoides*) in the northwest Atlantic. NAFO Sci. Coun. Studies, 10: 47-52.

Collie, J.S. (1985) Life history and production of three amphipod species on Georges Bank. Mar. Ecol. Prog. Ser. 36: 205-213.

Collie, J.S (1987) Food consumption by yellowtail flounder in relation to production of its benthic prey. Mar. Ecol. Prog. Ser. 22: 229-238.

Curtis, M.A. (1977) Life cycles and population dynamics of marine benthic polychaetes from the Disko Bay area of West Greenland. Ophelia 16: 9-58.

Dawe, E. G. (1988) Length-weight relationships for short-finned squid in Newfoundland and the effect of diet on condition and growth. Trans. Amer. Fish. Soc. 117: 591-599.

Dawe, E.G., E.L. Dalley, and W.W. Lidster (1997) Fish prey spectrum of short-finned squid (*Illex illecebrosus*) at Newfoundland. Can. J. Fish. Aquat. Sci. 54(Suppl. 1): 200-208.

Dawe, E.G., D.M. Taylor, P.J. Veitch, H.J. Drew, P.C. Beck, and P.G. O'Keefe (1997) Status of Newfoundland and Labrador snow crab in 1996. DFO Can. Stock Ass. Res. Doc. 97/07, 30p.

Dawe, E.G., H.J. Drew, and P.C. Beck. Status of Newfoundland and Labrador snow crab in 1997. DFO Can. Stock Ass. Res. Doc. (in prep.)

Deibel, D. (1988) Filter feeding by *Oikopleura vanhoeffeni*: grazing impact on suspended particles in cold ocean waters. Marine Biology. 99: 177-186.

Diamond, A.W., A.J. Gaston and R.G.B. Brown (1986). Converting PIROP counts of seabirds at sea to absolute densities. Can. Wildl. Serv. Prog. Note No. 164, 21p.

Diamond, A.W., A.J. Gaston and R.G.B. Brown. (1993) A model of the energy demands of the seabirds of Eastern and Arctic Canada. In: W.A. Montevecchi (Ed.) Studies of High-Latitude Seabirds. III. Can. Wildl. Serv. Occas. Pap. 77.

Dologov, A.V. (1997) Distribution, abundance, biomass and feeding by thorny skate (*Raja radiata*) in the Barents Sea. ICES CM 1997/G:04, pp. 21.

Dolgov, A.V. and K.V. Drevetnyak (1990) Estimation of rations and food consumption of deep-water redfish (*Sebastes mentella*) from the Norwegian-Barents Sea stock. ICES C.M. 1990/G: 11.

Edwards, R.L. (1968) Fishing resources of the North Atlantic area. The future of the fishing industry of the United States. Univ. of Washington Publ. In D.W. Gilbert (ed) Fisheries New Series 4: 52-60.

Ennis, G.P. (1973) Food, feeding and condition of lobsters *Homarus americanus*, throughout the seasonal cycle in Bonavista Bay. Newfoundland. J. Fish. Res. Bd. Ca. 30(12): 1905-1909.

Ennis, G.P., P.W. Collins, amd G. Dawe (1982) Fisheries and Population Biology of Lobsters (*Homarus americanus*) at Comfort Cove, Newfoundland. Can. Tech. Rep. Fish. Aquat. Sci. 1116, 45 p.

Ennis, G.P., P.W. Collins, and G. Dawe (1989) Fisheries and Population Biology of Lobsters (*Homarus americanus*) at St. Chads-Burnside, Newfoundland. Can. Tech. Rep. Fish. Aquat. Sci. 1651, 44 p.

Elliot, J.M and L. Persson (1978) The estimate of daily rates of food consumption for fish. J. Anim. Ecol. 47: 977-991. Quoted in Zamarro (1992).

Elliot, R.D., P.C. Ryan, and W.L. Lidster (1990) Winter diet of thick-billed murres in coastal Newfoundland waters. Studies in Avian Biology 14: 125-138.

Fauchuld, K. and P. Jumars (1979) The diet of worms: a study of polychaete feeding guilds. Oceanog. Mar. Biol. Ann. Rev. 17: 19-38.

Feldman, G., N. Kuring, C. Ng, W. Esaias, C.R. McClain, J. Elrod, N. Maynard, D. Endres, R. Evans, J. Brown, S. Walsh, M. Carle and G. Podesta (1989) Ocean Colour. Availability of the global data set. EOS, 70: 634-641.

Gartner, J.V., R.E. Crabtree, and K.J. Sulak. (1997) Feeding at depth In: D. J. Randall and A. P. Farrell. (eds.) Deep-sea fishes. Academic Press. San Diego. , pp. 115-193.

Gaskin, D.E. (1982) The ecology of whales and dolphins. London: Heinemann Educational Books Ltd., 459p.

Gaskin, D.E. (1992) Status of the harbour porpoise, *Phocoena phocoena*, in Canada. Can. Field-Nat. 106: 36-54.

Gaskin, D.E. and B.A. Blair (1977) Age determination of harbour porpoise, *Phocoena phocoena* (L.), in the Western North Atlantic. Canadian Journal of Zoology, 55:18-30.

Gerasimova, O.V. (1994) Pecularities of spring feeding by capelin (*Mallotus villosus*) on the Grand Bank in 1987-90. J. Northw. Atl. Fish. Sci. 17: 59-67.

Gilkinson, K., J.-M. Gagnon, and D. Schneider (1988) The sea urchin, *Stronglyocentrotus pallidus*, (G.O. Sars) on the Grand Bank of Newfoundland. In. R,. Burke, P. Mladenov, P. Lambert and R. Parsley (eds.) Echinoderm Biology, Proc. Six. Int. Echin. Conf. Victoria, 23-28 Aug 1987, pp. 467-473.

Gomes, M.C., R.L. Haedrich, and J.C. Rice (1992) Biogeography of groundfish assemblages on the Grand Bank. J. Northw. Atl. Fish. Sci. 14: 13-27.

Gomes, M.C., R.L. Haedrich, and M.G. Villagarcia (1995) Spatial and temporal changes in the groundfish assemblages on the north-east Newfoundland/Labrador Shelf, north-west Atlantic, 1978-1991. Fish. Oceanogr. 4: 85-101.

Gordon Jr., D.C., P. Schwinghamer, T.W. Rowell, J. Prena, K. Gilkinson, W.P. Vass and D.L. McKeown (1997) Studies in Canada on the impact of mobile fishing gear on benthic habitat and communities. Manuscript prepared for the Proceedings of the Conference on Effects of Fishing Gear on the Sea Floor of New England, Northeastern University, Ashland, MA. 30 May 1997.

Goudie, R.I. and C.D. Ankney (1989) Body size, activity budgets, and diets of sea ducks wintering in Newfoundland. Ecology 67: 1475-1482.

Grégoire, F. (1996). Description of the Atlantic mackerel (*Scomber scombrus* L.) fishery since 1985 and preliminary results for 1995. CAFSAC Res Doc 96/59, 80 p.

Grosslein, M.D., R.W. Langton, and M.P Sissenwine (1980) Recent fluctuations in pelagic fish stocks of the northwest Atlantic, Georges Bank region in relation to species interactions. Rapp. P-v. Réun. Cons. Int. Explor. Mer 177: 374-404.

Gushchin, A. V., and S. G. Podrazhanskaya (1983) Feeding of roundnose grenadier, *Coryphaenoides rupestris* Gunn., and its position in the trophic system of the North Atlantic. NAFO SCR Doc. 83/81, Serial No. N747. 14 p.

Hammill, M.O., and G.B. Stenson (1998) Estimated prey consumption by harp seals, (*Phoca groenlandica*), grey seals (*Halichoerus grypus*), harbour seals (*Phoca vitulina*) and hooded seals (*Cystophora cristatal*). J. Northw. Atl. Fish. Sci. (*In press*).

Hay, K. (1982) Aerial line-transect estimates of abundance of humpback, fin, and long-finned pilot whales in the Newfoundland-Labrador area. Report of the International Whaling Commission, 32:475-486.

Hay, K.A. (1985) Status of the humpback whale, *Megaptera novaeangliae*, in Canada. Canadian Field-Naturalist, 99:425-432.

Heyraud, M. (1979) Food ingestion and digestive transit time in the euphausiid *Meganyctiphanes norvegica* as a function of animal size. J. Plankton. Research 1: 301-312.

Hollibaugh, J.T., and J.A. Booth (1981) Observations on the dynamics and distribution of phytoplankton and primary production on the Grand Banks in the 1980 season. Section 4, Grand Banks Oceanographic Studies, Final Report, MacLaren Plansearch.

Hopkins, C.C.E. (1988) Energy content and production of the deep-water prawn *Pandalus borealis* (Kröyer) as a function of body size/age and season. ICES CM 1988/K:24 Ref. G.

Hopkins, C.C.E., and E.M. Nilssen (1990) Population biology of the deep-water prawn (*Pandalus borealis*) in Balsfjord, northern Norway: I. Abundance, mortality and growth. 1979-1983. J. Cons. int. Explor. Mer., 47: 148-166.

Hopkins, C.C.E., J.R. Sargent, and E.M. Nilssen (1993) Total lipid content, and lipid and fatty acid composition of the deep-water prawn *Pandalus borealis* from Balsfjord, northern Norway: growth and feeding relationships. Mar. Ecol. Prog. Ser. 96: 217-228.

Horwood, J. (1990) Biology and exploitation of the Mink Whale. CRC Press Inc., USA. 238 pp.

Houston, K.A., and R.L. Haedrich. (1986) Food habits and intestinal parasites of deep demersal fishes from the upper continental slope east of Newfoundland, northwest Atlantic Ocean. Mar. Biol. 92: 563-574.

Hutcheson, M., P. Stewart, and J. Spry (1981) The biology of benthic communities on the Grand Bank of Newfoundland (including the Hibernia area). In: Grand Banks Oceanographic Studies 3, Prepared for Mobil Oil by MacLaren Plansearch, 99 p.

Ichihara, T. (1966) The pygmy blue whale, *Balaenoptera musculus brevicauda*, a new subspecies from the Antarctica. In: Whales, dolphins and porpoises (Ed. by K.S. Norris), Berkeley: University of California Press, pp. 79-113.

Irwin, B., C. Caverhill and T. Platt (1986) Primary productivity on the Grand banks of Nwfoundland 1984. Can. Data. Rep. Fish. and Aquat. Sci., 579, 49 p.

Irwin B., W.G. Harrison, J. Anning, C. Caverhill, P. Dickie and T. Platt (1988) Phytoplankton production and distribution on the Grand Banks of Newfoundland in September 1985. Can. Data. Rep. Fish. and Aquat. Sci., 691, 82p.

Irwin B., C. Caverhill, D. Mossman, J. Anning, J. Horne and T. Platt (1989) Primary production on the Labrador Shelf during July 1985. Can. Data. Rep. Fish. and Aquat Sci., 760, 119 p.

Irwin, B., J. Anning, C. Caverhill, and T. Platt (1990) Primary production on the Labrador Shelf and in the Strait of Belle Isle in May 1998. Can. Data. Rep. Fish. and Aquat. Sci., 784, 96 p.

Jarre-Teichmann, A. (1996) Initial estimates on krill, The Alaska Gyre. In: D. Pauly, V. Christensen and N. Haggen (eds.) Mass-balance models of North-eastern Pacific Ecosystems: Proceedings of a workshop held at the Fisheries Centre, University of British Columbia, Vancouver, BC, Canada, November 6-10, 1995, 20 p.

Jarre-Teichmann, A., and S. Guenette (1996) Invertebrate Benthos. Southern BC Shelf Model. In: D. Pauly, V. Christensen and N. Haggen (eds.) Mass-balance models of North-eastern Pacific Ecosystems: Proceedings of a workshop held at the Fisheries Centre, University of British Columbia, Vancouver, BC, Canada, November 6-10, 1995, 38 p.

Jones, R. (1984) Some observations on energy transfer through the North Sea and Georges Banks food webs. Rapports et procès-verbaux des réuniuons 183: 204-217.

Keats, D. W. (1990) Food of winter flounder *Pseudopleuronectes americanus* in a sea urchin dominated community in eastern Newfoundland. Mar. Ecol. Prog. Ser. 60: 13-22.

Keats, D.W., D.H. Steele, and G.R. South (1986) Atlantic wolffish (*Anarhichas lupus* L.; Pisces: Anarhichidae) predation on green sea urchins (*Strongylocentrotus droebachiensis* (O.F. Mull.); Echinodermata: Echinoidea) in eastern Newfoundland. Can. J. Zool. 64: 1920-1925.

Keats, D.W., D.H. Steele, and G.R. South (1987) Ocean pout (*Macrozoarces americanus* (Bloch and Schneider) (Pisces:Zoarcidae)) predation on green sea urchins (*Strongylocentrotus droebachiensis* (O.F. Mull.) (Echinodermata: Echinoidea)) in eastern Newfoundland. Can. J. Zool. 65: 1515-1521.

Kenney, R.D., G.P. Scott, T.J. Thompson and H.E. Winn (1997) Estimates of prey consumption and trophic impacts in the USA Northeast continental shelf ecosystem. J. Northw. Atl. Fish. Sci. 22: 155-171.

Kennedy, V.S., and D.H. Steele (1971) The winter flounder (*Pseudopleuronectes americanus*) in Long Pond, Conception Bay, Newfoundland. J. Fish. Res. Board Can. 28: 1153-1165.

Kohler, A. C. (1967) Size at maturity, spawning season, land food of Atlantic halibut. J. Fish. Res. Board Can. 24: 53-66.

Kohler, A.C., and D.N. Fitzgerald (1969) Comparisons of food of cod and haddock in the Gulf of St. Lawrence and on the Nova Scotia Banks. J. Fish. Res. Board Can. 26: 1273-1287.

Kovalyov, S.M., and B.D. Kudrin (1973) Soviet investigations on capelin in the Northwest Atlantic in 1971 and 1972. ICNAF Redbook 1973, Part III: 121-126.

Konchina, Yu. V. (1986) Fundamental trophic relationships of the rockfishes *Sebastes mentella* and *Sebastes fasciatus* (Scorpaenidae) of the northwestern Atlantic. J. Ichthy. 26: 53-65. (originally publ. in Voprosy Ikhtiologii 6: 973-985)

Koslow, J.A., R.J. Kloser and A. Williams (1997) Pelagic biomass and community structure over the mid-continental slope off southeastern Australia based upon acoustic and midwater trawl sampling. Mar. Ecol. Prog. Ser. 146: 21-35.

Kulka, D. (1986) Estimates of discarding by the Newfoundland offshore fleet in 1985 with reference to trends over the past 5 years. NAFO SCR Doc. 86/95., 20 p.

Kulka, D. (1997) Discarding of cod (*Gadus morhua*) in the Northern cod and Northern shrimp directed trawl fisheries. NAFO Sci. Coun. Studies, 29: 67-79.

Kulka, D.W. and E.M. Deblois (1996) Non traditioanl groundfish species on Labrador Shelf and Grand Banks wolffish, monkfish, white hake and winter (blackback) flounder. DFO Atl. Fish. Res. Doc. 96/97, 49 p.

Kulka, D.W., E.M. Deblois and D.B. Atkinson (1996) Non-traditional groundfish species on

Labrador Shelf and Grand Banks - Skate. DFO Atl. Fish. Res. Doc. 96/98, 29 p.

Knoechel, R. and D. Steel-Flynn (1989) Clearance rates of *Oikopleura* ~~in~~ cold coastal Newfoundland waters: a predictive model and its trophodynamic implications. Mar. Ecol. Prog. Ser. 53: 257-266.

Lambert, D.G. (1960) The food of the redfish, *Sebastes marinus* (L.) in the Newfoundland area. J. Fish. Res. Board Can. 17: 235-243.

Langton, R.W., and R.E. Bowman (1980) Food of fifteen Northwest Atlantic Gadiform fishes. NOAA Tech. Rep. NMFS SSRF-740. 23 p.

Lawson, J.W. and G.B. Stenson. (1995). Historic variation in the diet of harp seals (*Phoca groenlandica*) in the northwest Atlantic. pp. 261-269. In: Whales, Seals, Fish and Man. (Eds.) A. S. Blix, Ø. Ultang, and L. Walløe.

Lawson, J.W. and G.B. Stenson (1997) Diet of northwest Atlantic harp seals (*Phoca groenlandica*) in offshore areas. Can. J. Zool. 75: 2095-2106.

Lawson J.W., G.B. Stenson and D.G. McKinnon (1995) Diet of harp seals (*Phoca groenlandica*) in nearshore waters of the northwest Atlantic during 1990-1993. Can. J. Zool. 73: 18.5-1818.

Lear, W.H., and L.S. Parsons (1993) History and management of the fishery for northern cod in NAFO Divisions 2J, 3K and 3L, In: L.S. Parsons and W.H. Lear [eds.] Perspectives on Canadian marine fisheries management. Can. Bull. Fish. Aquat. Sci. 226, pp. 55-89.

Lien, J. (1985) Wet and Fat: Whales and seals of Newfoundland and Labrador. St. John's: Breakwater Books, Ltd., 136p.

Lilly, G.R. (1980 The food of Arctic cod, *Boreogadus saida* (Lepechin), off Labrador in autumn, 1978. CAFSAC Res. Doc. 80/4. 11 p.

Lilly, G.R. (1984) Annual variability in the diet of Atlantic cod (*Gadus morhua* L.) off southern Labrador and northeast Newfoundland (Div. 2J+3K) in autumn, 1977-1982. NAFO SCR Doc. 84/79, Serial No. N868. 12 p.

Lilly, G.R. (1987) Interactions between Atlantic cod (*Gadus morhua*) and capelin (*Mallotus villosus*) off Labrador and eastern Newfoundland: a review. Can. Tech. Rep. Fish. Aquat. Sci. 1567: vii + 37 p.

Lilly, G.R. (1991) Interannual variability in predation by cod (*Gadus morhua*) on capelin (*Mallotus villosus*) and other prey off southern Labrador and northeastern Newfoundland. ICES mar. Sci. Symp. 193: 133-146.

Lilly, G.R., and A.M. Fleming (1981) Size relationships in predation by Atlantic cod, *Gadus morhua* , on capelin, *Mallotus villosus* , and sand lance, *Ammodytes dubius* , in the Newfoundland area. NAFO Sci. Counc. Stud., (no. 1), 41-45.

Lilly, G.R., R. Wells and J. Carscadden (1981) Estimates of the possible consumption of capelin by the cod stocks in Divisions 2J+3KL and 3NO. NAFO SCR Doc. 81/II/8.

Lilly, G.R., H. Hop, D.E. Stansbury and C.A. Bishop (1994) Distribution and abundance of polar cod (*Boreogadus saida*) off southern Labrador and eastern Newfoundland. ICES C.M. 1994/O:6, 21p.

Lilly, G.R., D.G. Parsons, and P.J. Veitch (1998) Spatial structure of northern shrimp (*Pandalus borealis*) off Labrador and eastern Newfoundland (northwest Atlantic). *In* Proceedings of the North Pacific Symposium on Invertebrate Stock Assessment and Management. *Edited by* G.S. Jamieson and A. Campbell. Can. Spec. Publ. Fish. Aquat. Sci. 125. pp. 265-271.

Lilly, G.R., P.A. Shelton, J. Brattey, N. Cadigan, E.F. Murphy, and D.E. Stansbury (1999) An assessment of the cod stock in NAFO Divisions 2J+3KL. DFO Can. Stock Ass. Sec. Res. Doc. 99/42.

Lockyer, C. (1981) Estimation of the energy costs of growth, maintenance and reproduction in the female minke whale, (*Balaenoptera acutorostrata*), from the Southern Hemisphere. Report of the International Whaling Commission, 31:337-343.

Longhurst, A. (1995) Seasonal cycles of pelagic production and consumption. Prog. Oceanog. 36: 77-167.

Longhurst, A., S. Sathyendranath, T. Platt and C. Caverhill (1995) An estimate of global primary prodution in the ocean from satellite radiometer data. J. Plankton Research 17(6) 1245-1271.

Lovrich, G.A., and B. Sainte-Marie (1997) Cannibalism in the snow crab, *Chionoecetes opilio* (O. fabricus) (Brachyura: majidae), and its potential importance to recruitment. J. Exp. Mar. Biol. Ecol. 211: 225-245.

McClaren, I.A., M.J. Tremblay, C.J. Corkett and J.C. Roff (1989) Copepod production on the Scotian Shelf based on life-history analyses and laboratory readings. Can. J. Fish. Aquat. Sci. 46: 560-583.

MacDonald, J.S., and K.G. Waiwood (1987) Feeding chronology and daily ration calculations for winter flounder (*Pseudopleuronectes americanus*), American plaice (*Hippoglossoides platessoides*), and ocean pout (*Macrozoarces americanus*) in Passamaquoddy Bay, New Brunswick. Can. J. Zool. 65: 499-503.

Madin, L.P., and D. Deibel (1998) Feeding and metabolism of thaliaceans. In: Biology of the Pelagic Tunicates, ed. by Q. Bone. Oxford University Press.

Martin, T. (1990) Whales and Dolphins. Salamander Press.

Mauchline, J. (1980) The biology of Euphausiids. Adv. mar. Biol. 373-623.

Mauchline, J. (1985) Growth and production of Euphausiacea (Crustacea) in the Rockall Trough. Mar. Biol. 90: 19-26.

Mertz, G., and R.A. Myers (1998) A simplified formulation for fish production. Can. J. Fish. Aquat. Sci 55(2): 478-484.

Messieh, S., H. Powles, and G. Côté (1979) Food and feeding of the Atlantic herring (*Clupea harengus* L.) in the Gulf of St. Lawrence and adjacent waters. CAFSAC Res. Doc. 79/15.19 p.

Miller. D.S. (1992) Results of an acoustic survey for capelin (*Mallotus villosus*) in NAFO Division 3L in 1992. NAFO SCR Doc. 92/57, 4p.

Miller, D.S. (1993a) Observations and studies on SA2+Div. 3K capelin in 1992. DFO Atl. Fish. Res. Doc. 93/10, 10p.

Miller, D.S. (1993b) Results from an acoustic survey for capelin in Divisions 3NO in 1992. NAFO SCR Doc. 93/21, 5p.

Miller, R.J., and P.G. O'Keefe (1981) Seasonal and depth distribution, size and molt cycle of the Spider crabs, *Chionoecetes opilio, Hyas araneaus,* and *Hyas coarctatus* in a Newfoundland Bay. Can. Tech. Rep. Fish. Aquat. Sci. 1003, 18 p.

Mills, E.I., and R.O. Fournier (1979) Fish production and the marine ecosystems of the Scotian Shelf, Eastern Canada. Mar. Biol 54: 101-108.

Mitchell, E. (1973) Draft report on humpback whales taken under specific scientific permit by eastern Canadian land stations, 1969-1971. Report of the International Whaling Commission, 23:138-154.

Mitchell, E. (1974) Present status of northwest Atlantic fin and other whale stocks. In: The whale problem: A status report W.E. Schevill (ed.), Cambridge: Harvard University Press, pp. 108-169.

Mitchell, E. (1975) Trophic relationships and competition for food in the northwest Atlantic whales. Proceedings of the Canadian Zoological Society, 1974:123-133.

Mitchell, E.D., and D.G. Chapman (1977) Preliminary assessment of stocks of northwest Atlantic sei whales (*Balaenoptera borealis*). Report of the International Whaling Commission, 1:117-120.

Montevecchi, W.A. (1993) Seabird indication of squid stock conditions. Journal of Cephalopod Biology 2: 57-63.

Montevecchi, W.A., and L.M. Tuck (1987) Newfoundland Birds: Exploitation, Study, Conservation. Nuttal Ornithological Club, Cambridge, Massachusetts. 272 p.

Montevecchi, W.A., and R.A. Myers (1997) Centurial and decadal oceanographic influences on changes in northern gannet populations and diets in the Northwest Atlantic: Implications for climate change. ICES Journal of Marine Science 54: 608-614.

Montevecchi, W.A., D.K. Cairns and V.L Birt. (1988a) Migration of post smolt Atlantic salmon (Salmo salar) off northeastern Newfoundland, as inferred from tag recoveries in seabird colony. Can. J. Fish. Aquat. Sci. 45: 568-571.

Montevecchi, W.A., V.L. Birt, and D.K. Cairns (1988b) Dietary changes of seabirds associated with local fisheries failures. Biological Oceanography 5(3): 153-161.

Montevecchi, W.A., V.L. Birt-Friesen and D.K. Cairns (1992) Reproductive energetics and prey harvest by Leach's Storm-Petrels in the northwest Atlantic. Ecology 73: 823-832.

Montevecchi, W.A., R.E. Ricklefs, I.R. Kirkham, and D. Gabaldon (1984) Growth energetics of nestling northern gannets, *Sula bassanus*. Auk 101: 257-262.

Montevecchi, W.A., D.K. Cairns, A.E. Burger, R.D. Elliot and J. Wells (1987) The status of common black-headed gulls, *Larus ridibundus* in Newfoundland and Labrador. American Birds 41: 197-203.

Mooi, R., and M. Telford (1982) The feeding mechanism of the sand dollar, *Echinarchnius parma* (Lamarck). In: J. Lawrence (ed.) Echinoderms: Proc. Internat. Conf., Tampa bay., A.A. Balkema, Rotterdam.

Moores, J.A., G.H. Winters, and L.S. Parsons (1975) Migrations and biological characteristics of Atlantic mackerel (*Scomber scombrus*) occurring in Newfoundland waters. J. Fish. Res. Bd. Can. 32:1347-1357.

Morgan, M.J., and W.R. Bowering (1995) Maturity at size and age of Greenland halibut in NAFO subarea and divisions 2KLM. NAFO SCR Doc. 95/54, 19 p.

Morgan, M.J., W.B. Brodie, S.J. Walsh and D. Orr (1997) An assessment of Divisions 3LNO American plaice. NAFO SCR Doc. 97/60. 47 p.

NAFO (1987) Sealing Statistics for 1985. NAFO Stat. Bull., 35: 319-320.

NAFO (1989) Sealing Statistics for 1986. NAFO Stat. Bull., 36: 303-304.

NAFO (1990) Sealing Statistics for 1987. NAFO Stat. Bull., 37: 293-294.

Nelson, D., and J. Lien (1996) The status of the long-finned pilot whale, *Globicephala melas*, in Canada. Can. Field Nat. 110 (3): 511-524.

Nesis, K.I. (1965) Bioeconoses and biomass of benthos of the Newfoundland-Labrador region. Fisheries Research Board of Canada Translation Series No. 1357, 75 p.

Nettleship, D.N., and G. Chapdelaine (1988) Population size and status of northern gannets, Sula bassanus, in North America. Journal of Field Ornithology 59: 120-127.

O'Dor, R.K. and E.G. Dawe (1998) *Illex Illecebrosus*. In. Rodhouse, P. G.; Dawe, E. G.; O'Dor, R. K. (eds.) . Squid recruitment dynamics. The genus *Illex* as a model. The commercial *Illex* species. Influences on variability. FAO Fisheries Technical Paper. No. 376. Rome, FAO, pp. 77-194.

Palsbel, P.J and 18 authors (1997) Genetic tagging of humpback whales. Nature 388, 21 August 1997, pp. 767-769.

Panasenko, L.D. (1981) Diurnal rhythms and rations of capelin feeding in the Barents Sea. ICES C.M. 1981/H:26.

Parsons, D.G., G.R. Lilly and G.J. Chaput (1986) Age and growth of northern shrimp *Pandalus borealis* off northeastern Newfoundland and southern Labrador. Trans. Amer. Fish. Soc. 115: 872-881.

Parsons, D.G., and P.J. Veitch (1991) Assessment of the northern shrimp fishery from northeastern Newfoundland to southern Davis Strait (Divisions 3K to 0B). CAFSAC Res. Doc. 91/64: 50 p.

Parsons, D.G., and P.J. Veitch (1998) Status of northern shrimp (*Pandalus borealis*) resources in areas off Baffin Island, Labrador and Northeastern Newfoundland - Interim Review. CSAS Res. Doc. 98/xx: 41p.

Pauly, D. (1989) Food consumption by tropical and temperate fish populations: some generalisations. J. Fish. Biol. 35 (Supplement A): 11-20.

Pauly, D., M.L. Soriano-Bartz and M.L.D. Palomares (1993) Improved construction, parameterisation and interpretation of steady-state ecosystem models. In: Christensen, V and D. Pauly (eds) Trophic models of aquatic ecosystems. ICLARM Conf. Proc. 26: 1-13.

Pauly, D., and V. Christensen (1996) Mass Balance Models of North-eastern Pacific Ecosystems. Fisheries Centre Research Reports Vol. 4., No. 1. UBC, Canada. 131 p.

Petrov, V.N. (1973) Maturity, feeding and length and age composition of white hake, *Urophycis tenuis* (Mitch.), in ICNAF Subarea 3, 1969-1972. ICNAF Redbook 1973, Part III: 101-104.

Pitt, T.K. (1973) Food of American plaice (*Hippoglossoides platessoides*) from the Grand Bank, Newfoundland. J. Fish. Res. Board Can. 30: 1261-1273.

Pitt, T.K. (1971) Assessment of American plaice stocks in ICNAF Divisions 3L and 3N. ICNAF Res. Doc. 71/111, 13 pp.

Pitt, T.K. (1975) Status of the yellowtail flounder fishery in ICNAF Divisions 3L,3N and 3O. ICNAF Res. Bull. 11:125-134.

Pitt, T.K. (1976) Food of yellowtail flounder on the Grand Bank and a comparison with American plaice. ICNAF Res. Bull.12: 23-27.

Platt, T., C. Caverhill and S. Sathyendranath (1991) Basin-scale estimates of oceanic primary production by remote sensing: the North Atlantic. J. Geophysical Research 96 (C8): 15,147-15,159.

Podrazhanskaya, S.G. (1993) Feeding habits of mesopelagic species of fish and estimation of plankton graze in the Northwest Atlantic. NAFO Sci. Coun. Studies 19: 79-85.

Polovina, J.J. (1984) Model of a coral reef ecosystem. The ECOPATH model and its application to French Frigate Shoals. Coral Reefs 3(1):1-11.

Pomeroy, L.R. (1979) Secondary production mechanisms of continental shelf communities. In: R.J. Livingstone (Ed.) Ecological processes in coastal and marine ecosystems, pp. 163-186.

Pomeroy, L.R., and D. Deibel (1986) Temperature regulation of bacterial activity during the spring bloom in Newfoundland coastal waters. Science, vol. 233, no. 4761: 359-361.

Power, D. (1995) Status of redfish in subarea 2 and division 3K. DFO Atl. Fish. Res. Doc.

95/25, 25 p.

Power, D. (1997) Redfish in NAFO division 3LN NAFO SCR Doc. 97/64, 37 p.

Power, D. and A.A.Vaskov (1992) Abundance and biomass estimates of redfish (*S. mentella*) Div. 3LN from Russian Groundfish Surveys from 1984-91. NAFO SCR Doc. 92/59, 9p.

Power, D., D.B. Atkinson and W.B. Brodie (1996) Division 3O redfish - status update. DFO Atl. Fish. Res. Doc. 96/115, 19 p.

Power, D. and D.M. Parsons (1998) The status of the redfish resource in NAFO division 3LN NAFO SCR Doc. 98/74.

Prasad, K.S., and R.L. Haedrich (1993) Primary production estimates on the Grand Banks of Newfoundland, north-west Atlantic ocean, derived from remotely sensed chlorophyll. Int. J. Remote Sensing 14(17): 3299-3304

Prena, J, T.W. Rowell, P. Schwinghamer, K. Gilkinson and D.C. Gordon, Jr. (1996) Grand Banks otter trawling impact experiment: 1. Site selection processes with a description of macrofaunal communities. Can. Tech. Rep. Fish. Aquat. Sci. 2094, 38 p.

Purcell, J. (1996) Lower trophic levels. Alaska Gyre In: D. Pauly, V. Christensen and N. Haggen (eds.) Mass-balance models of North-eastern Pacific Ecosystems: Proceedings of a workshop held at the Fisheries Centre, University of British Columbia, Vancouver, BC, Canada, November 6-10, 1995, pp. 16-19.

Rae, B.B. (1969) The food of the witch. Marine Research, Dept. of Agriculture and Fisheries for Scotland. 1969 (2): 23p.

Rice, J.C. (1992) Multispecies interactions in marine ecosystems: current approaches and implications for study of seabird populations, in: Wildlife 2001:Populations (D.R. McCullough and R.H. Barrett, Eds), Elsevier, London, pp. 586-601.

Reddin, D. (1973) Ecology and feeding habits of the American Lobster (*Homarus americanus* (Milne-Edwards 1837)) in Newfoundland. Msc. Thesis, Memorial University of Newfoundland, Canada. 101 p.

Ricker, W.E. (1946) Production and utilisation of fish populations. Ecol. Monogr. 16: 373-391.

Rikhter, V.A. (1987) On estimating instantaneous natural mortality rate in the Irminger redfish. ICES CM 1987/G:27.

Robertson, A.I. (1979) The relationship between annual production, biomass ratios and life spans for marine macrobenthos. Oecologia 38: 193-202.

Roby, D.D., K.L. Brink, and D.N. Nettleship (1981) Measurements, chick meals and breeding distribution of dovekies (*Alle alle*) in Northwest Greenland. Arctic 34: 241-248.

Rodríguez-Marín, E., A. Punzón, and J. Paz (1995) Feeding patterns of Greenland halibut (*Reinhardtius hippoglossoides*) in Flemish Pass (Northwest Atlantic). NAFO Sci. Coun. Studies 23: 43-54.

Ross, S. (1993) Food and feeding of the hooded seal in Newfoundland. M.Sc. thesis. Memorial University, St. Johns, Newfoundland.

Sakshaug, E. (1997) Biomass and productivity distributions and their variability in the Barents Sea. ICES J. Mar. Sci. 54: 341-350.

Sameoto, D.D. (1976) Respiration rates, energy budgets, and molting frequencies of three species of euphausiids found in the Gulf of St. Lawrence. J. Fish. Res. Board. Can. 33: 2568-2576.

Sathyendranath, S., A. Longhurst, C.M. Caverhill and T. Platt (1995) Regionally and seasonally differentiated primary prodution in the North Atlantic. Deep Sea Research

42(10): 1773-1802.

Savvatimsky, P.I. (1989a) Investigations of roughhead grenadier (*Macrourus berglax* L) in the northwest Atlantic, 1967-83. NAFO Sci. Coun. Studies 13: 59-75.

Savvatimsky, P.I. (1989b) Distribution and biology of common grenadier (*Nezumia bairdi*) from trawl surveys in the northwest Atlantic, 1969-83. NAFO Sci. Coun. Studies 13: 53-58.

Schulz, N. (1990) A new attempt to calculate consumption rates for cod (*Gadus morhua* L.) in the Western Baltic. ICES C.M. 1990/J:15.

Schneider, D.C., J.M. Gagnon and K.D. Gilkinson (1987) Patchiness of epibenthic megafauna on the outer Grand Banks of Newfoundland. Mar. Ecol. Prog. Ser. 39: 1-13.

Scott, J.S. (1971) Abundance of groundfishes on the Scotian Shelf. Fish. Res. Bd. Canada. Tech. Rept. 260., 17 pp.

Scott, J. S. (1973) Food and inferred feeding behavior of northern sand lance (*Ammodytes dubius*). J. Fish . Res. Board Can. 30: 451-454.

Scott, W.B., and M.G. Scott (1988) Atlantic Fishes of Canada. Can. Bull. Fish. Aquat. Sci. 219: 731 p.

Sergeant, D.E. (1962) The biology of the pilot or pothead whale *Globicephala melaena* (Traill) in Newfoundland waters. Bull. Fish. Res. Board Can. 132: 84 p.

Shackell, N.L., P.A. Shelton, J.M. Hoenig and J.E. Carscadden (1994) Age- and sex-specific survival of northern Grand Bank capelin (*Mallotus villosus*). Can. J. Fish. Aquat. Sci., 51: 642-649.

Shelton, P.A., J.E. Carscadden, and J.M. Hoenig (1993) Risk evaluation of the 10% harvest rate procedure for capelin in NAFO Division 3L, p. 193-201. In S.J. Smith, J.J. Hunt, and D. Rivard [eds.] Risk evaluation and biological reference points for fisheries management. Can. Spec. Publ. Fish. Aquat. Sci. 120: 442p.

Shelton, P.A., G.B. Stenson, B. Sjare and W.G. Warren (1996a) Model estimates of harp seal numbers-at-age for the northwest Atlantic. NAFO Sci. Coun. Studies, 26:1-14.

Shelton, P.A., D.E. Stansbury, E.F. Murphy, G.R. Lilly and J. Brattey (1996b) An assessment of the cod stock in NAFO divisions 2J+3KL. NAFO SCR Doc. 97/62, 56 p.

Shelton, P.A., W.G. Warren, G.B. Stenson and J.W. Lawson (1997) Quantifying some of the major sources of uncertainty associated with estimates of harp seal prey consumption. Part II: Uncertainty in consumption estimates associated with population size, residency, energy requirements and diet. J. Northw. Atl. Fish. Sci., 22: 303-315.

Shumway, S.E., H.C. Perkins, D.F. Schick and A.P. Stickney (1985) Synopsis of the biological data on the pink shrimp, *Pandalus borealis* Kroyer, 1838. NOAA Tech. Rep. NMFS 30 FAO Fish. Synop. 144: 57 p.

Simon, J.E., and K.T. Frank (1996) An assessment of the skate fishery in Division 4VsW. DFO Atl. Fish. Res Doc. 95/71.

Sissenwine, M.P., E.B. Cohen and M.D. Grosslein (1984) Structure of the Georges Bank Ecosystem. Rapp. P.-v. Réun. Cons. int. Explor. Mer. 183: 243-254.

Sjare, B., G.B. Stenson and E.A. Perry. (1996) Summary of the catch and catch-at-age of harp seals in the northwest Atlantic, 1946-1994. NAFO Sci. Coun. Stud. 26:115-118.

Sklepovych, B.O., and W.A. Montevecchi (1989) The world's largest documented colony of Leach's storm petrels on Baccalieu Island, Newfoundland. American Birds 43: 36-42.

Smayda, T.J. (1993) Experimental manipulations of phytoplankton + zooplankton + ctenophore communities, and foodweb roles of the ctenophore, *Mnemiopsis*. ICES CM 1993/L:68.

Snelgrove, P.V.R., and C.A. Butman (1994) Animal-sediment relationships revisited: cause versus effect. Oceanography and Marine Biology: an Annual Review 32: 111-177.

Stansbury, D., C.A. Bishop, E.F. Murphy and M.B. Davis (1995) An assessment of the cod stock in NAFO Div. 3NO. NAFO SCR Doc., 95/70.

Steele, D. H. (1963) Pollock (*Pollachius virens* (L.)) in the Bay of Fundy. J. Fish. Res. Board Can. 20: 1267-1314.

Stenson, G.B., M.O. Hammill and J.W. Lawson (1997) Predation by harp seals in Atlantic Canada: preliminary consumption estimates for Arctic cod, capelin and Atlantic cod. J. Northw Atl. Fish. Sci. 22:137-154.

Stenhouse, I.J., and W.A. Montevecchi (1999) Increasing and expanding populations of breeding northern fulmars, *Fulmaris glacialis*, in the northwest Atlantic. Colonial Waterbirds. (Under revision).

Stillwell, C.E., and N.E. Kohler (1985) Food and feeding ecology of the swordfish *Xiphias gladius* in the western North Atlantic ocean with estimates of daily ration. Mar. Ecol. Prog. Ser.22: 239-247.

Storey, A.E., and J. Lien (1985) Development of the first North American colony of manx shearwaters. Auk 102: 395-401.

Strong, K.W. (1981) Seasonal occurrence and distribution of zooplankton in waters over the Grand Banks of Newfoundland. In: Grand Banks Oceanographic Studies, Prepared for Mobil Oil by MacLaren Plansearch, 32 p.

Sullivan, B.K. (1980) *In situ* feeding behaviour of *Sagitta elegans* and *Eukrohnia hamata* (Chaetognatha) in relation to the vertical distribution and abundance of prey at ocean Station "P". Limnol. Oceanogr. 25: 317-326.

Swan, B. K., and D. Clay (1979) Feeding study on silver hake (*Merluccius bilinearis*) taken from the Scotian Shelf and ICNAF Subarea 5. ICNAF Res. Doc. 79/49, Serial No. 5388. 17 p.

Taylor, D.M., and P.G. O'Keefe.(in prep.). Assessment of the 1997 Newfoundland and Labrador snow crab fishery. Can. Stock Ass. Res. Doc. (in prep)

Tempieman, W. (1965) Some instances of cod and haddock behaviour and concentrations in the Newfoundland and Labrador areas in relation to food. ICNAF Spec. Publ. 6: 449-461.

Templeman, W. (1966) Marine resources of Newfoundland. Fish. Res. Board Can., Bull. 154.

Templeman, W. (1982) Stomach contents of the thorny skate, *Raja radiata*, from the northwest Atlantic. J. Northw. Atl. Fish. Sci. 3: 123-126.

Templeman, W. (1984) Migrations of thorny skate, *Raja radiata*, tagged in the Newfoundland area. J. Northw. Atl. Fish.Sci. 5(1): 55-64.

Templeman, W. (1985) Stomach contents of Atlantic wolffish (*Anarhichas lupus*) from the Northwest Atlantic. NAFO Sci. Coun. Studies 8: 49-51.

Turner, J.T., and J.C. Roff (1993) Trophic levels and trophospecies in marine plankton: lessons from the microbial foodwebs. Marine Microbial Food Webs 7(2): 225-248.

Vesin, J.P., W.C. Leggett, and K.W. Able (1981) Feeding ecology of capelin (*Mallotus villosus*) in the estuary and western Gulf of St. Lawrence and its multispecies implications. Can. J. Fish. Aquat. Sci. 38(3):257-267.

Vinogradov, V.I. (1972) Studies of the food habits of silver and red hake in the Northwest Atlantic area, 1965-67. ICNAF Res. Bull. 9: 41-50.

Vinogradov, V.I. (1983) Food relationships between silver and red hakes and other fish species on Georges Bank and in adjacent waters. NAFO SCR Doc. 83/80, Serial No. N746, 21 p.

Vinther, M. (1989) Some notes on the biology of the starry ray, *Raja radiata*, in the North Sea. As reported in Anon (1989) Report of the Multispecies Assessment Working Group, ICES CM 1989/Assess: 20, pp. 42- 43.

Waiwood, K.G., J. Majkowski and G. Keith (1980) Food habits and consumption rates of cod from the southwestern Gulf of St. Lawrence. CAFSAC Res. Doc. 80/37.

Walsh, S.J., W.B. Brodie, M.J. Morgan, W.R. Bowering, D. Orr and M. Veitch (1997) An assessment of the Grand Bank yellowtail flounder stock in NAFO Divisions 3LNO. NAFO SCR Doc. 97/72, 54 p.

Walsh, S.J., W.B. Brodie, M. Veitch, D. Orr, C. McFadden and D. Maddock-Parsons (1998) An assessment of the Grand Bank yellowtail flounder stock in NAFO Divisions 3LNO. NAFO SCR Doc. 98/72, 79 p.

Warren, W.G., P.A. Shelton and G.B. Stenson (1997) Quantifying some of the major sources of uncertainty associated with estimates of harp seal prey consumption. Part I: Uncertainty in the estimates of harp seal population size. J. Northw. Atl. Fish. Sci., 22: 289-302.

Welch, H.E., M.A Bergmann, T.D.Siferd, K.A. Martin, M.F. Curtis, R.E. Crawford, R.J. Conover, and H. Hop (1992) Energy flow through the marine ecosystem of the Lancaster Sound region, arctic Canada. Arctic 45 (4): 343-357.

Wheeler, J.P., and G.H. Winters (1984). Migrations and stock relationships of east and southeast Newfoundland herring as indicated from tagging studies. J. Northw. Atl. Fish. Sci. 5:121-129.

Wheeler, J.P., G.H. Winters and R. Chaulk (1989). Newfoundland east and southeast coast herring - 1988 assessment. CAFSAC Res Doc 89/40, 86 pp.

Wieczorek, S.K. and R.G. Hooper (1995) Relationship between diet and food availability in the snow crab *Chionoecetes opilio* (O. fabricus) in Bonne Bay, Newfoundland J. Crust. Biol. 15 (2): 236-247.

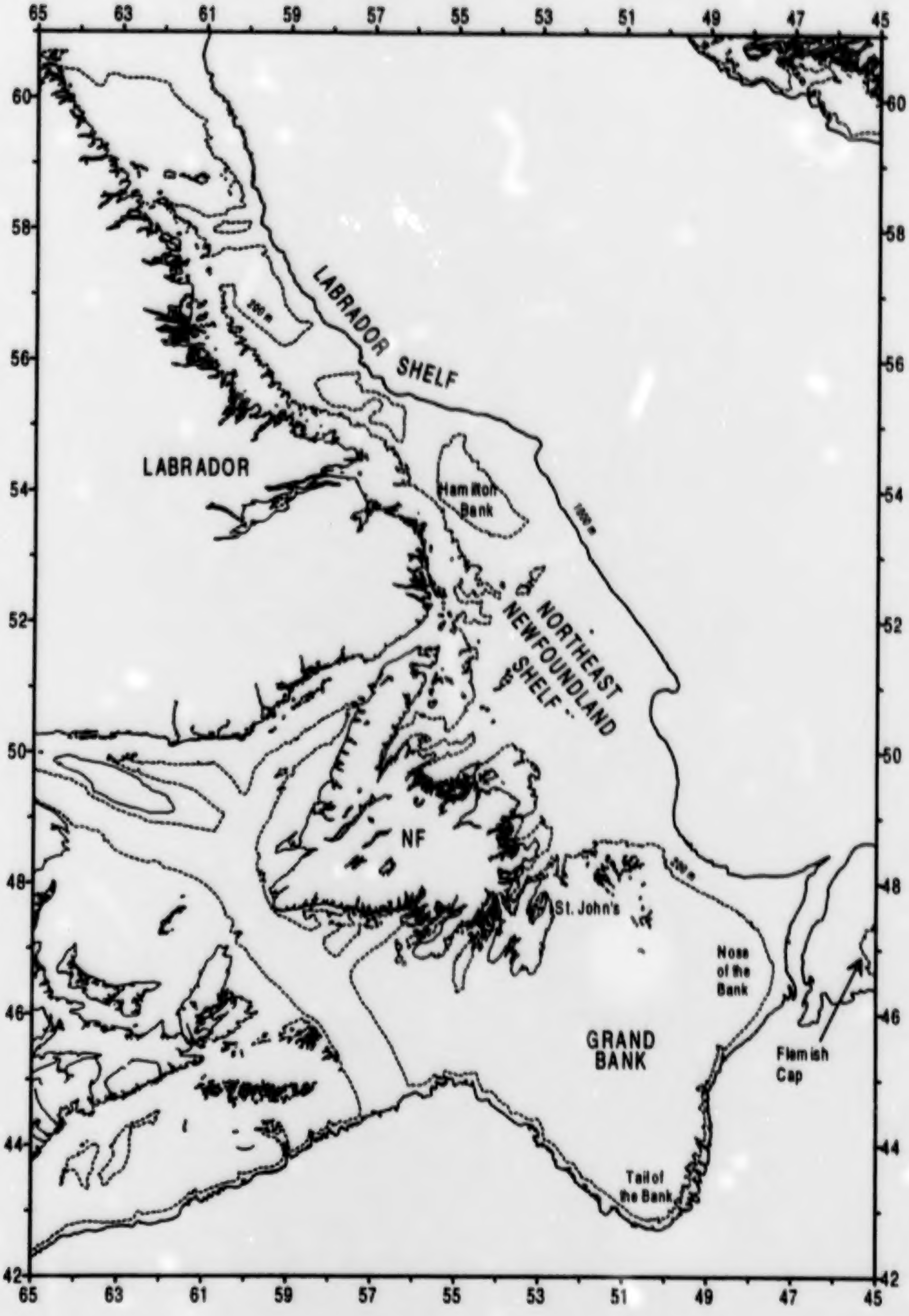
Wienberg, R. 1981. On the food and feeding habits of *Pandalus borealis* Kroyer 1838. Arch. FischWiss 31(3): 123-137.

Wildish, D.J., A.J. Wilson and B. Frost (1989) Benthic macrofaunal production of Browns bank, Northwest Atlantic. Can. J.Fish. Aquat. Sci. 46: 584-590.

Winters, G.H. (1983) Analysis of the biological data and demographic parameters of Northern sand lance, *Ammodytes dubius*, from the Newfoundland Grand Bank. Can. J. Fish. Aquat.Sci. 40: 409-419.

Yanulov, K.P. (1962) Feeding habits of "beaked" redfish (*Sebastes mentella* Travin) in the Newfoundland-Labrador area. ICNAF Redbook 1962, Part III. 132-140.

Zamarro, J. (1992) Feeding behaviour of the American plaice (*Hippoglossoides platessoides*),on the southern Grand Bank of Newfoundland. Netherlands J. Sea Res. 29(1-3): 229-238.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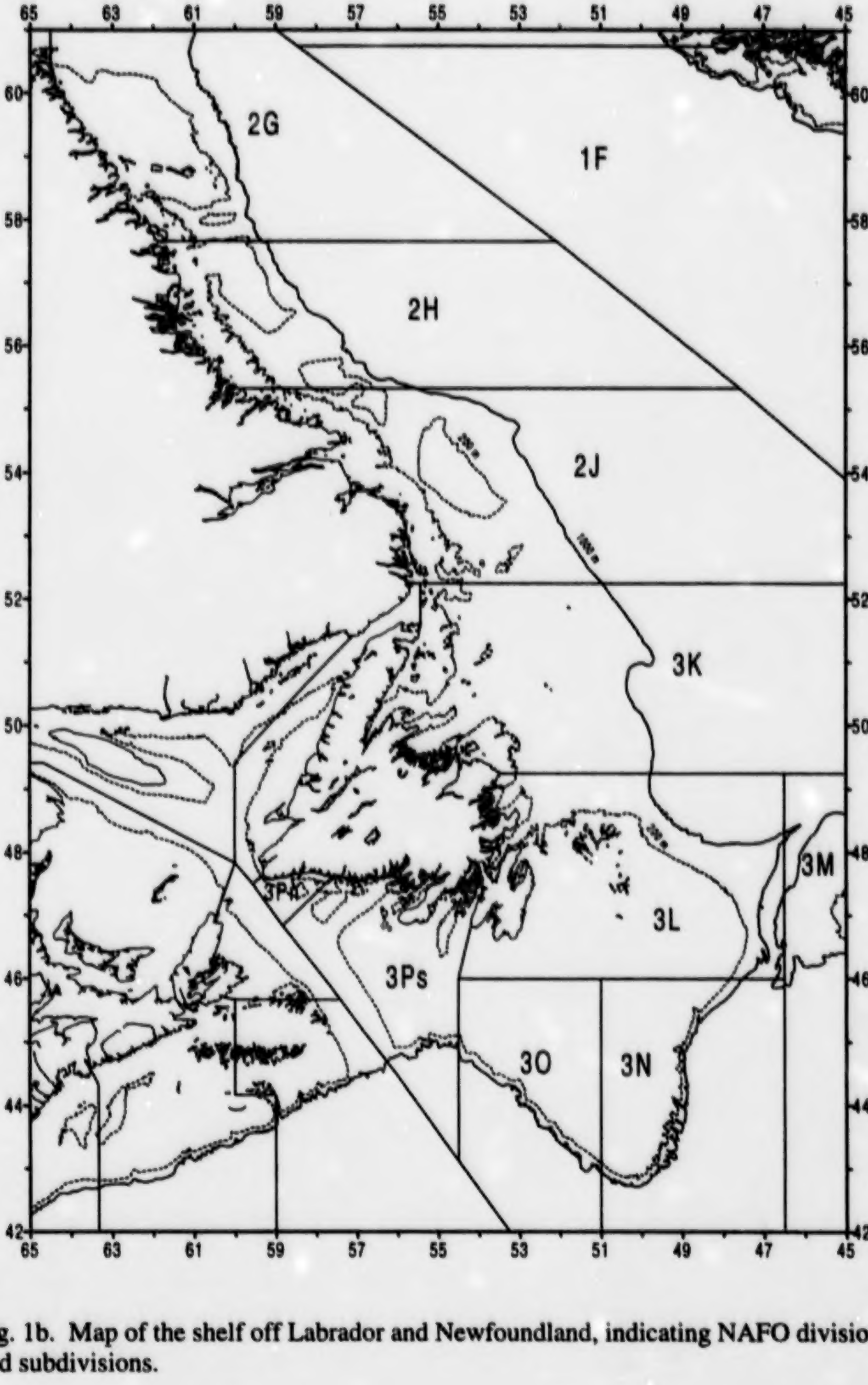
46
44
42
200 m
LABRADOR SHELF
LABRADOR
Hamilton Bank
1000 m
NORTHEAST NEWFOUNDLAND SHELF
NF
200 m
St. John's
Nose of the Bank
GRAND BANK
Flemish Cap
Tail of the Bank

Fig. 1a. Map of the shelf off Labrador and Newfoundland, indicating the major shelf areas and banks.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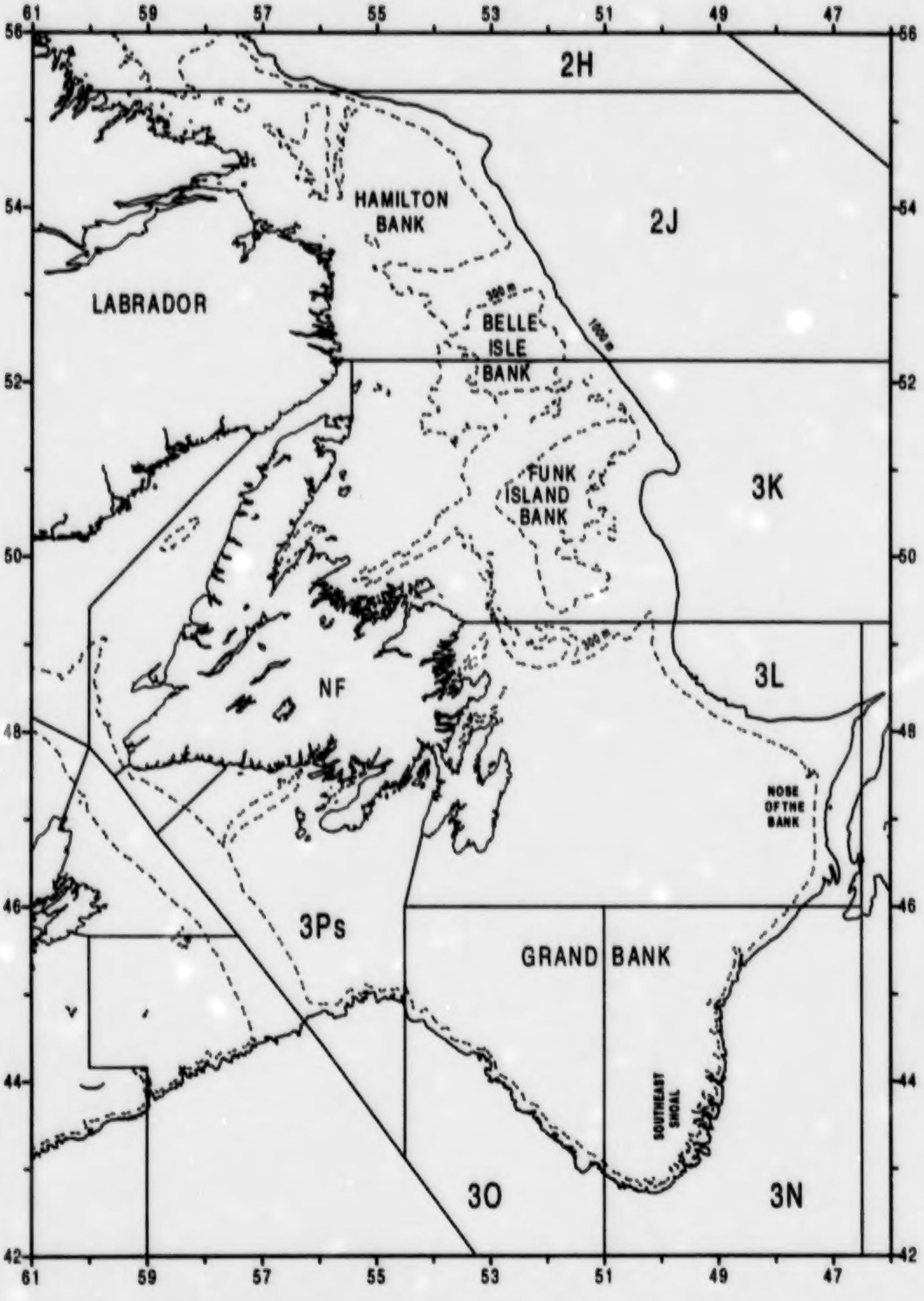
2G
1F
2H
2J
3K
3L
3M
3Pn
3Ps
3O
3N
200 m
1000 m

Fig. 1b. Map of the shelf off Labrador and Newfoundland, indicating NAFO divisions and subdivisions.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46
44
42
2H
2J
3K
3L
3Ps
3O
3N
HAMILTON BANK
LABRADOR
BELLE ISLE BANK
300 m
1000 m
FUNK ISLAND BANK
NF
NOSE OF THE BANK
GRAND BANK
SOUTHEAST SHOAL

Fig. 1c. Map of the study area from southern Labrador to the southern Grand Bank (divisions 2J3KLNO).

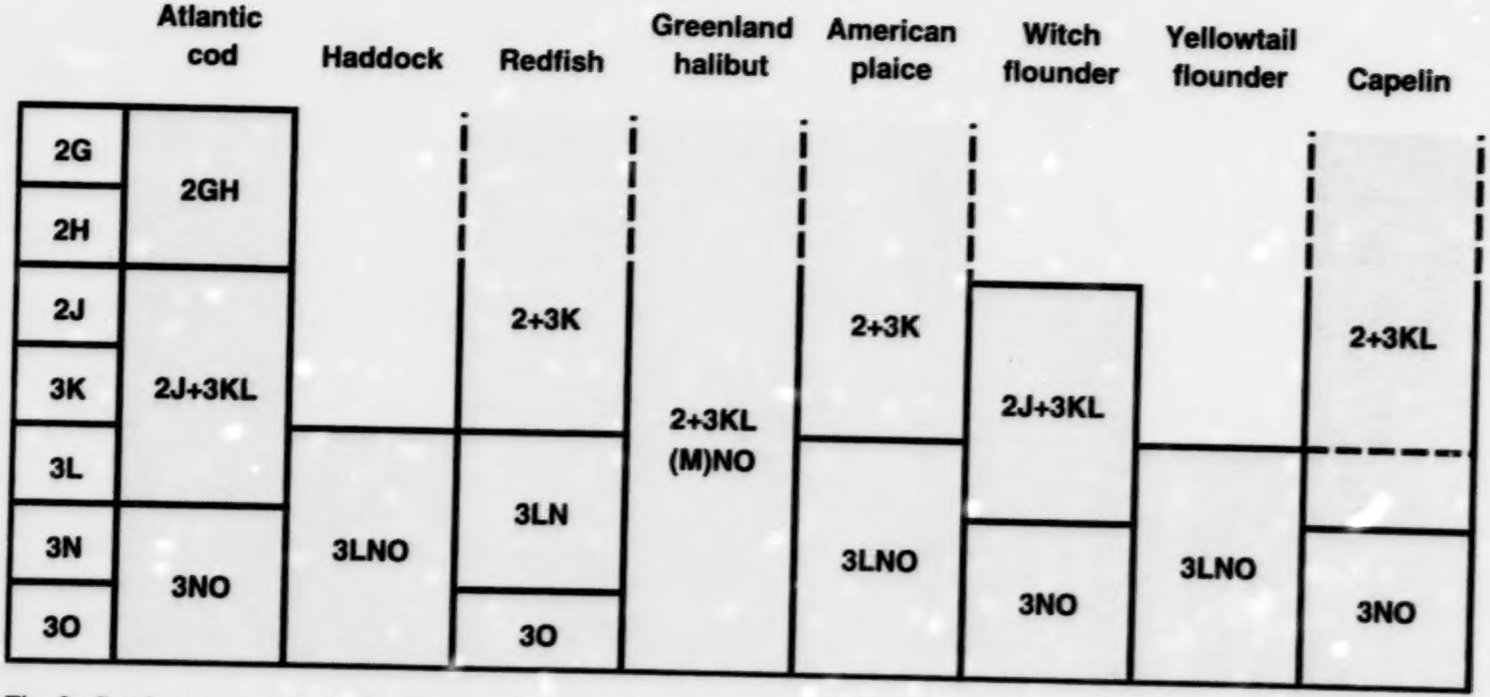
Atlantic cod
Haddock
Redfish
Greenland halibut
American plaice
Witch flounder
Yellowtail flounder
Capelin
2G
2H
2J
3K
3L
3N
3O
2GH
2J+3KL
3NO
3LNO
2+3K
3LN
3O
2+3KL
(M)NO
2+3K
3LNO
2J+3KL
3NO
3LNO
2+3KL
3NO

Fig. 2. Stock structure of major commercial fish species on the Labrador Shelf, the Northeast Newfoundland Shelf and Grand Bank. Dotted lines north of 2J indicate that the stock boundary extends to the northern end of Subarea 2. The dotted line between 3K and 3L in the 2+3KL capelin stock is a reminder that during 1985-1987 the stock was assessed as two stocks; 2+3K and 3L.

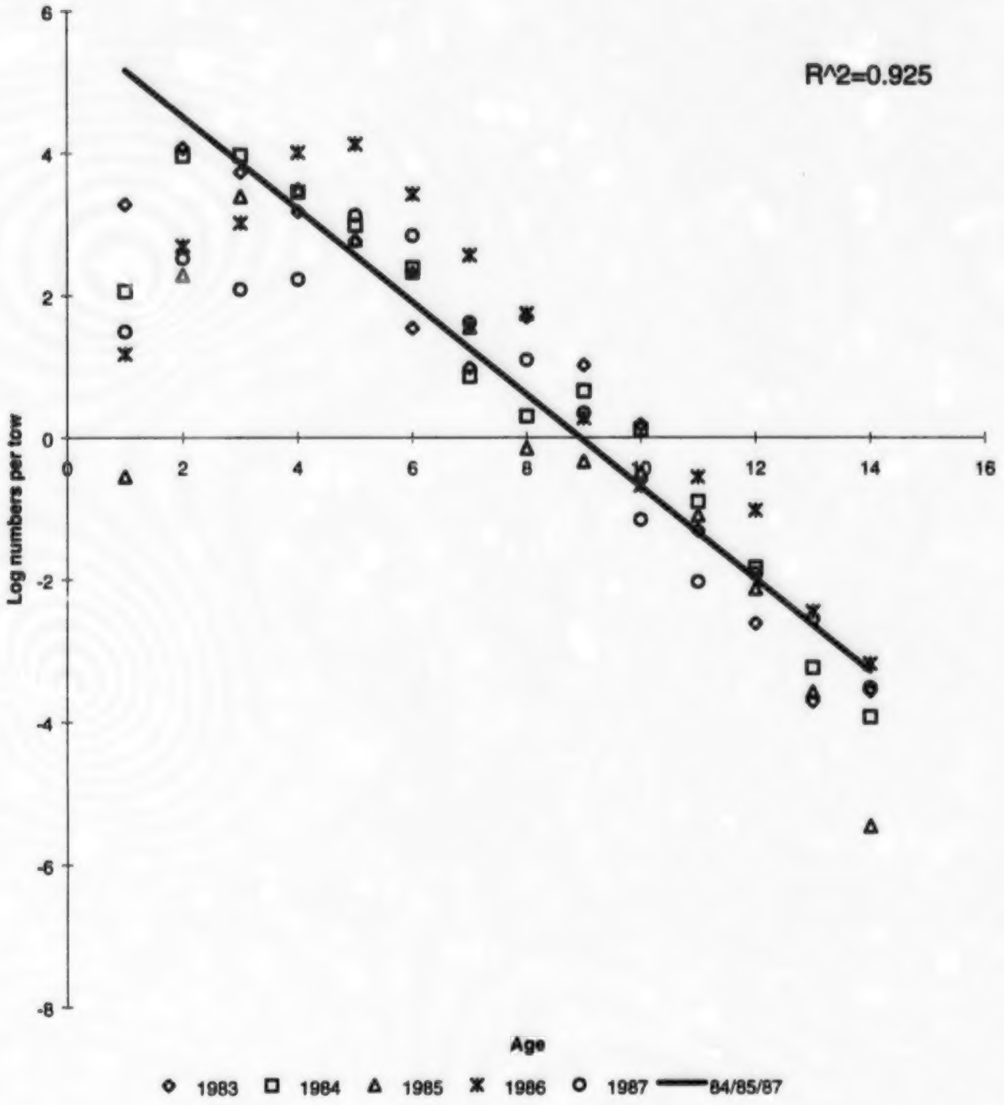

Fig. 3. Catch curve analysis of cod survey data (numbers per tow), ages 3-13, for years 1984, 1985, and 1987.

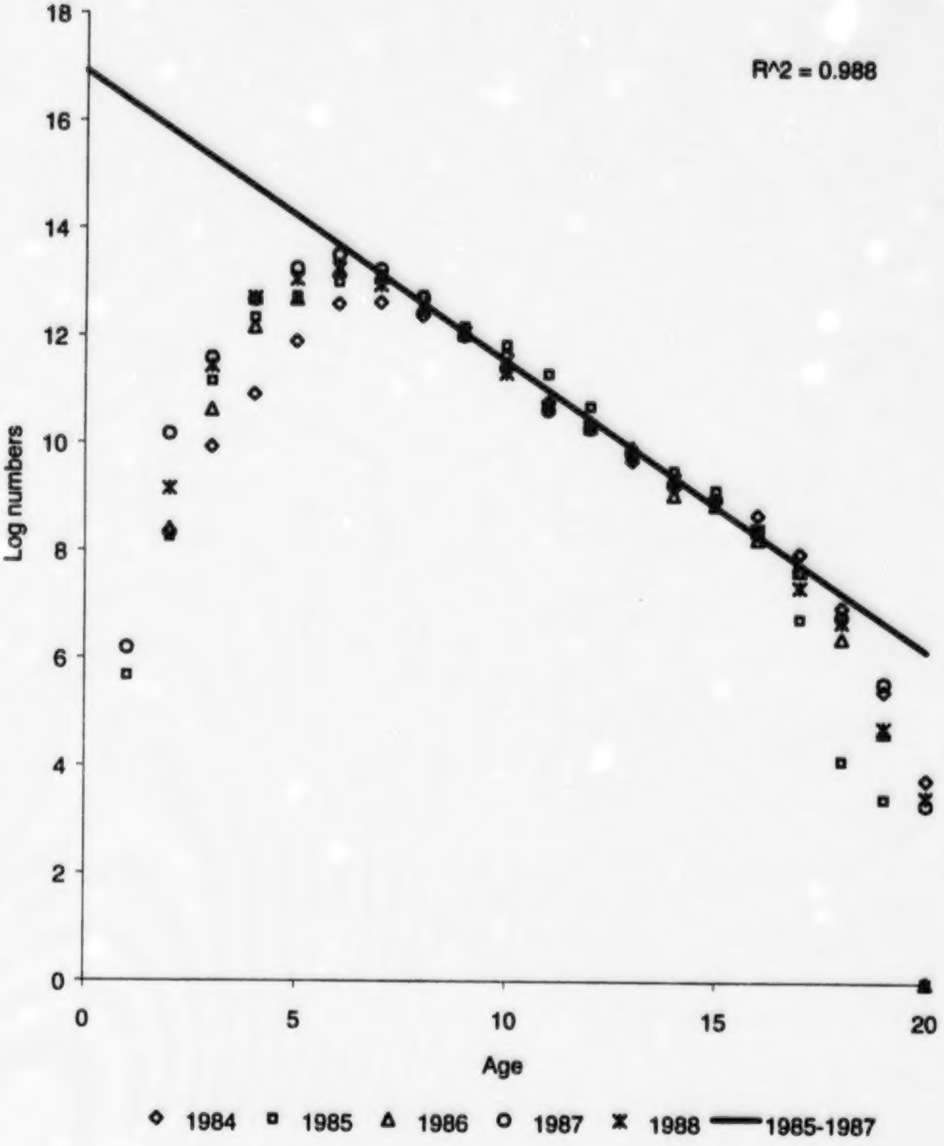

Fig. 4. Catch curve analysis of American plaice survey data, ages 7-17, 1985-1987.

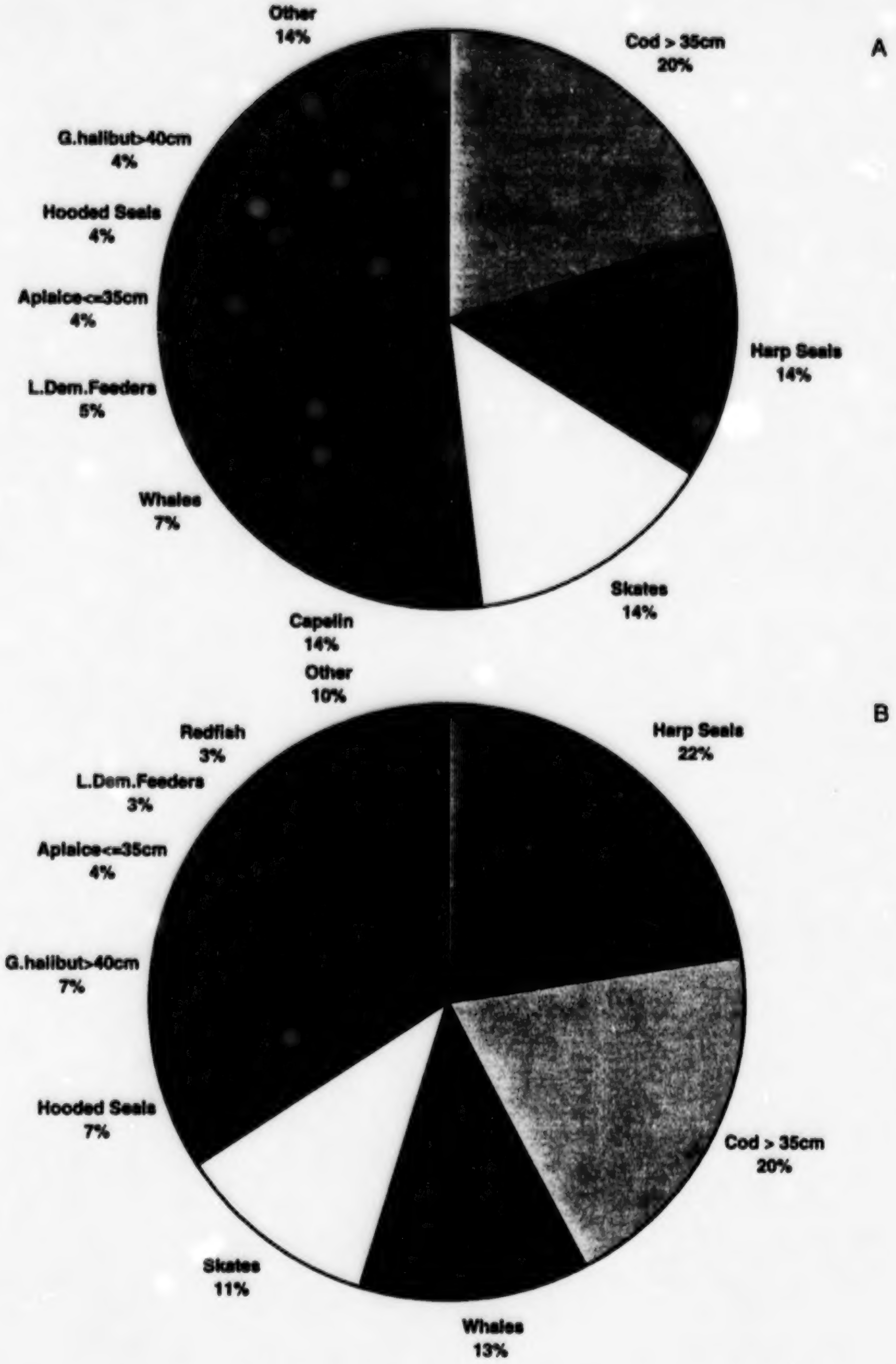

Fig. 5. Composition of vertebrate predators on (A) all prey and (B) fish prey.

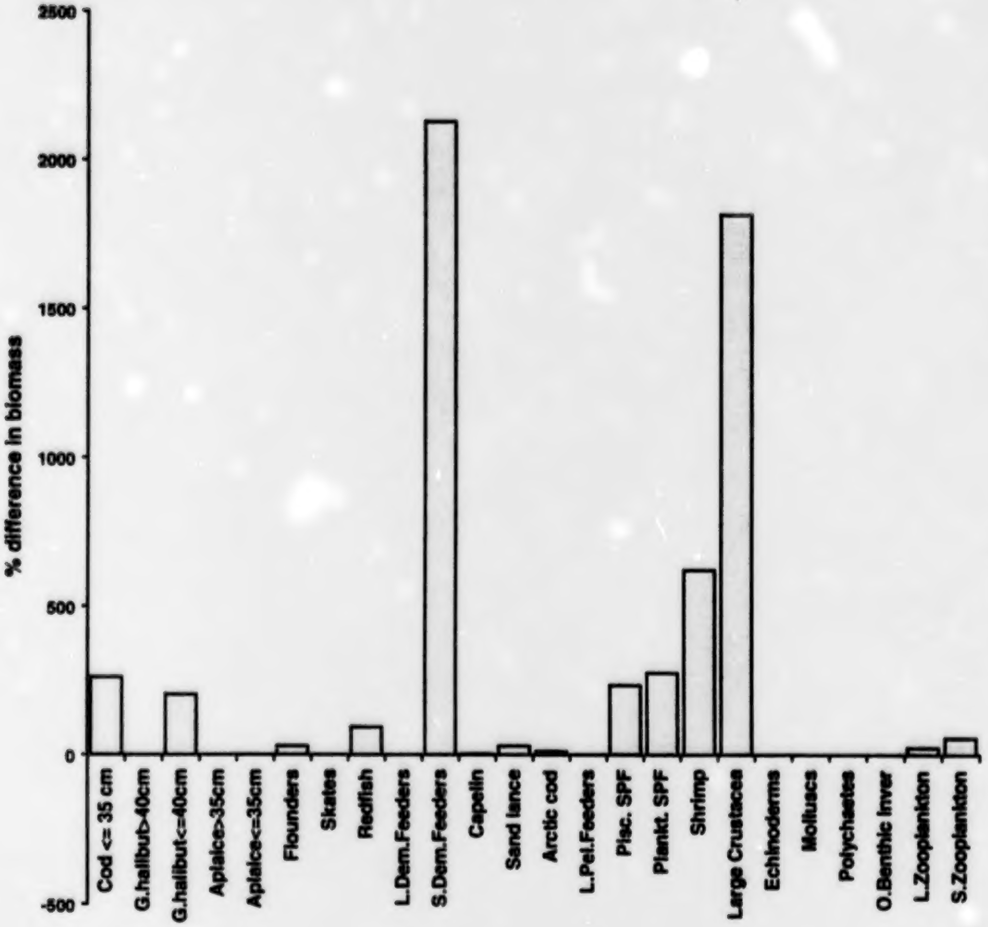

Fig. 6. Percentage difference between the biomass in the unbalanced model and the biomass in the balanced Model 1.

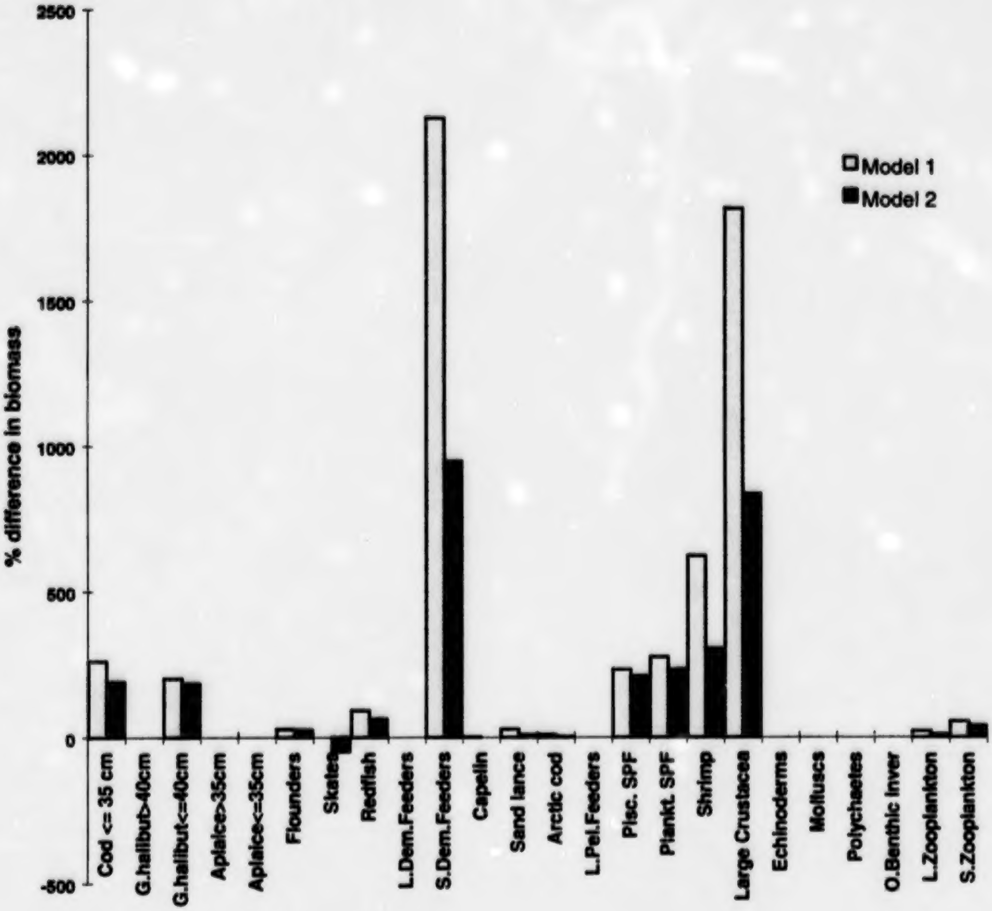

Fig. 7. Percentage difference between the biomass in the unbalanced model and the biomass in the balanced Models 1 and 2.

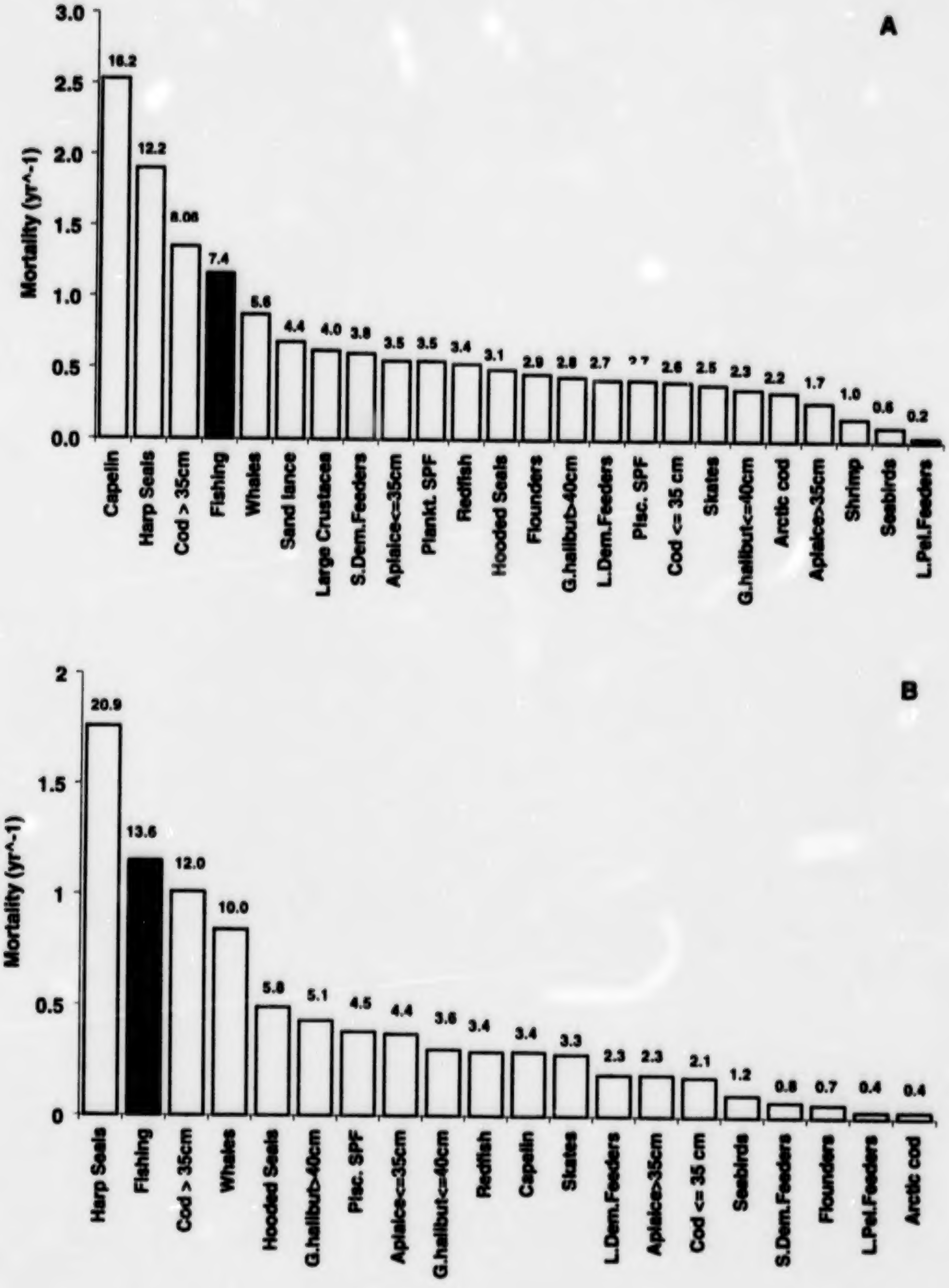

Fig. 8. Distribution of predation mortality among vertebrate predators on all prey (A) and all predators on vertebrate prey (B). The percentage figures include fishing.

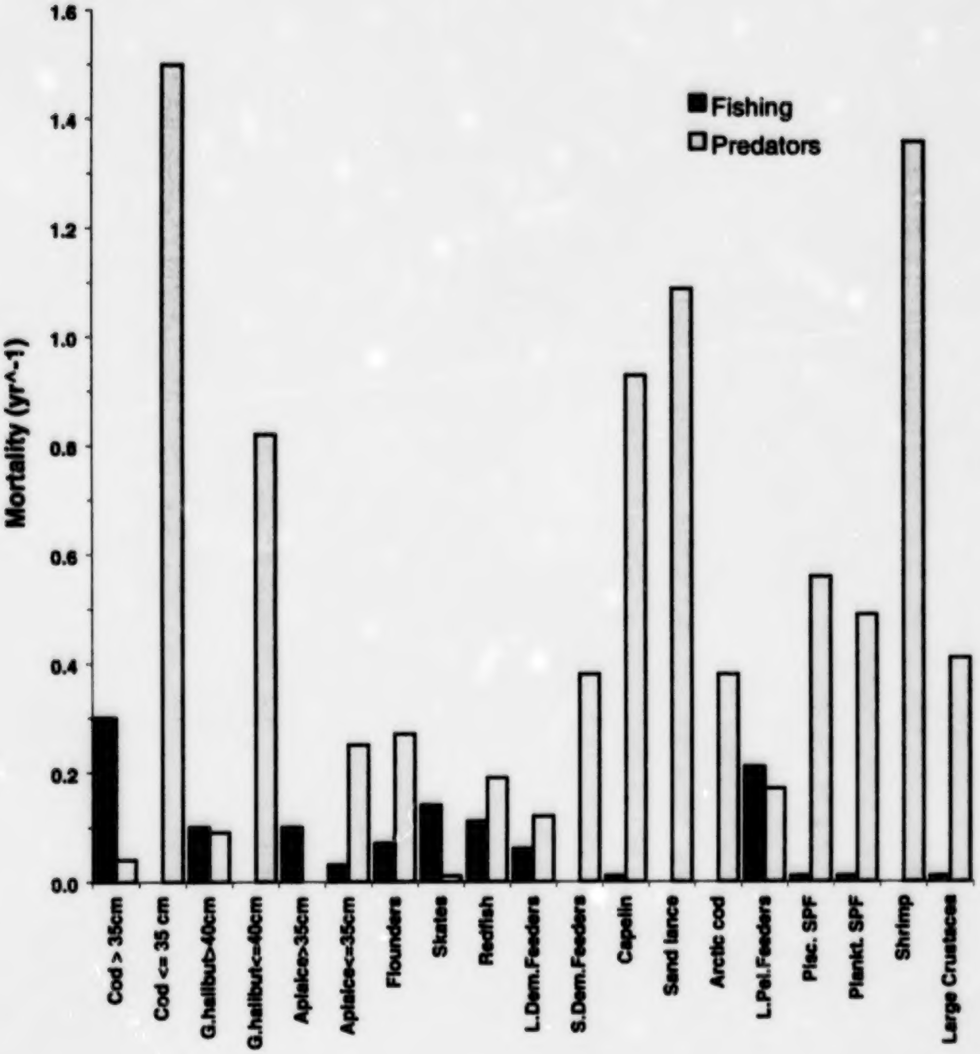

Fig. 9. Comparison of fishing mortality and predation mortality on individual prey groups.

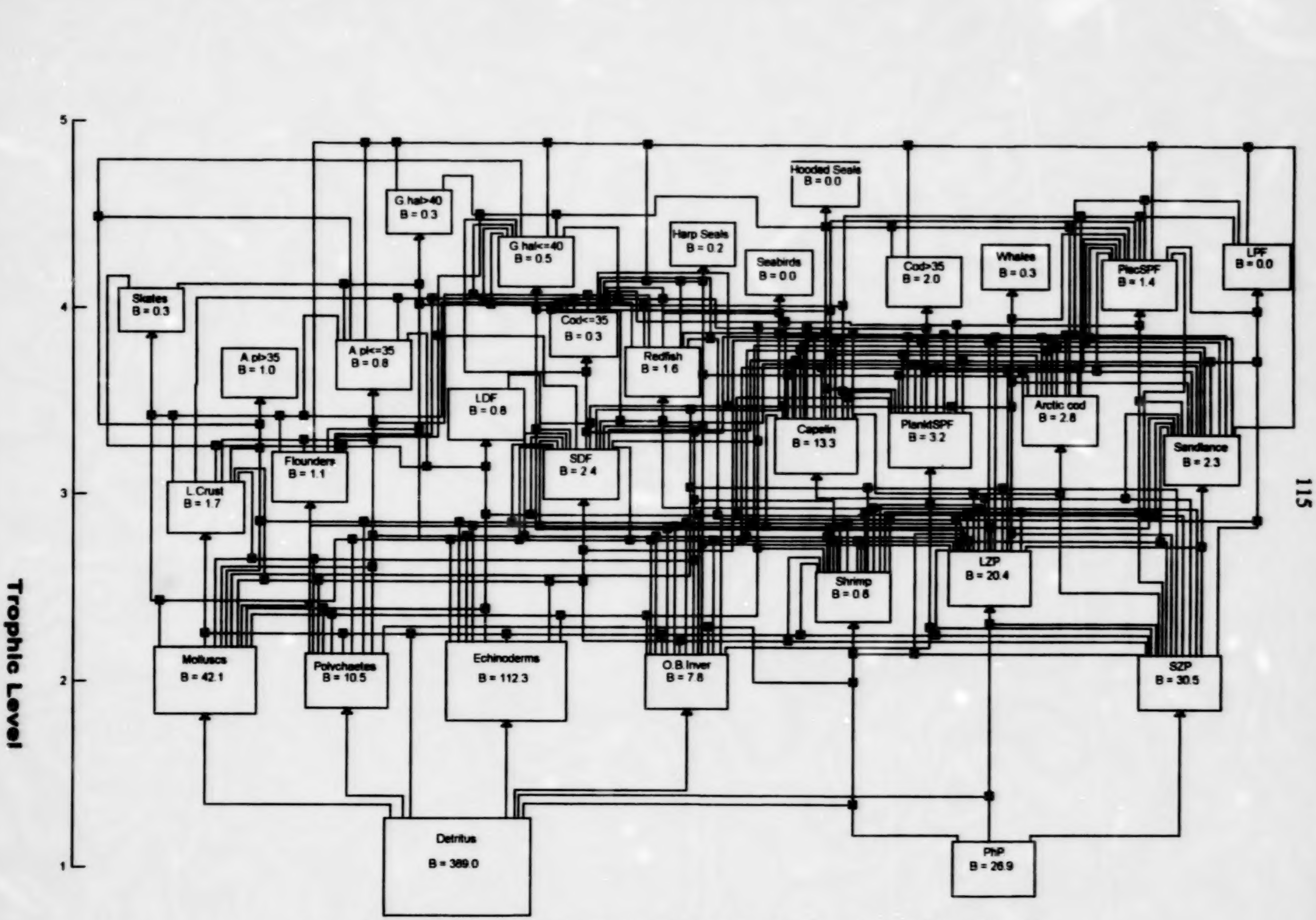
Trophic Level
5
4
3
2
1
Hooded Seals B = 0.0
G.hal>40 B = 0.3
Harp Seals B = 0.2
G.hal<=40 B = 0.5
Seabirds B = 0.0
Cod>35 B = 2.0
Whales B = 0.3
PlacSPF B = 1.4
LPF B = 0.0
Skates B = 0.3
Cod<=35 B = 0.3
A.pl>35 B = 1.0
A.pl<=35 B = 0.8
Redfish B = 1.6
LDF B = 0.8
Arctic cod B = 2.8
Capelin B = 13.3
PlanktSPF B = 3.2
Flounders B = 1.1
SDF B = 2.4
Sandlance B = 2.3
L.Crust B = 1.7
Shrimp B = 0.8
LZP B = 20.4
Molluscs B = 42.1
Polychaetes B = 10.5
Echinoderms B = 112.3
O.B.Inver B = 7.8
SZP B = 30.5
Detritus B = 389.0
PhP B = 26.9

Figure 10 Flow diagram of the Newfoundland-Labrador Ecopath model depicting the linkages between Ecopath groups.

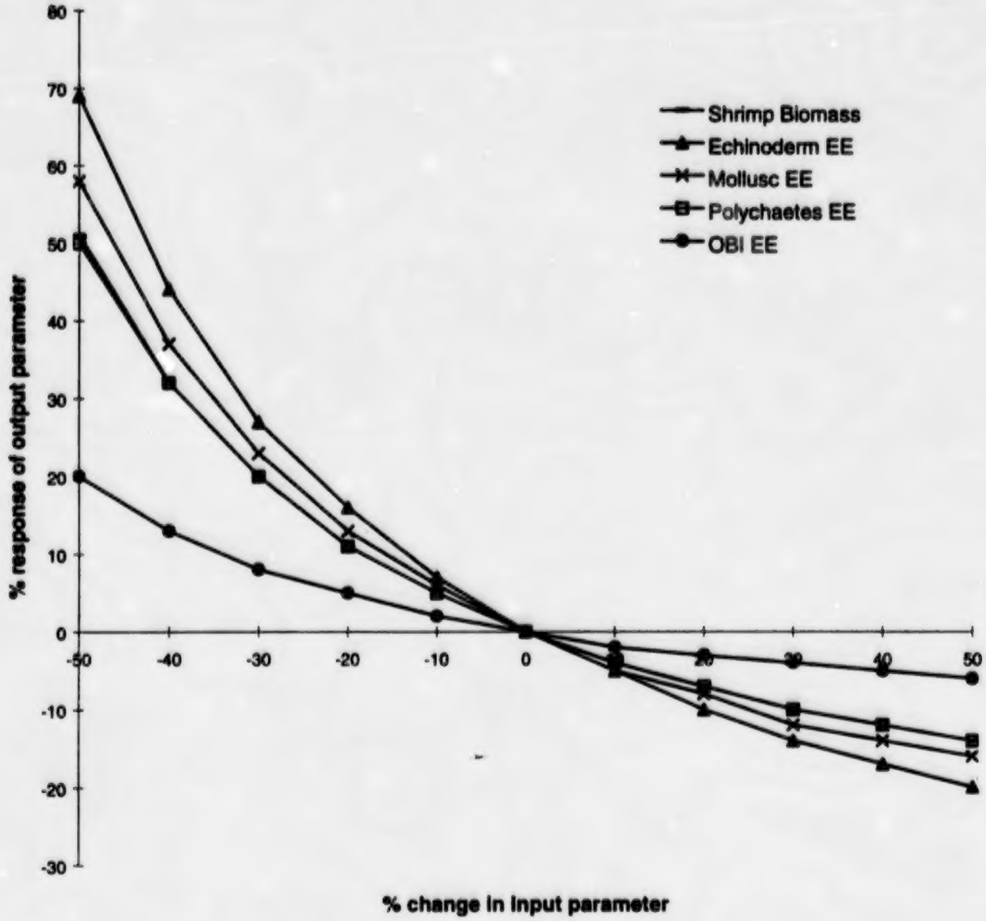

Fig. 11. Sensitivity of the shrimp, echinoderms, molluscs, polychaetes and other benthic invertebrates to the large crustacea input parameters PB and EE.

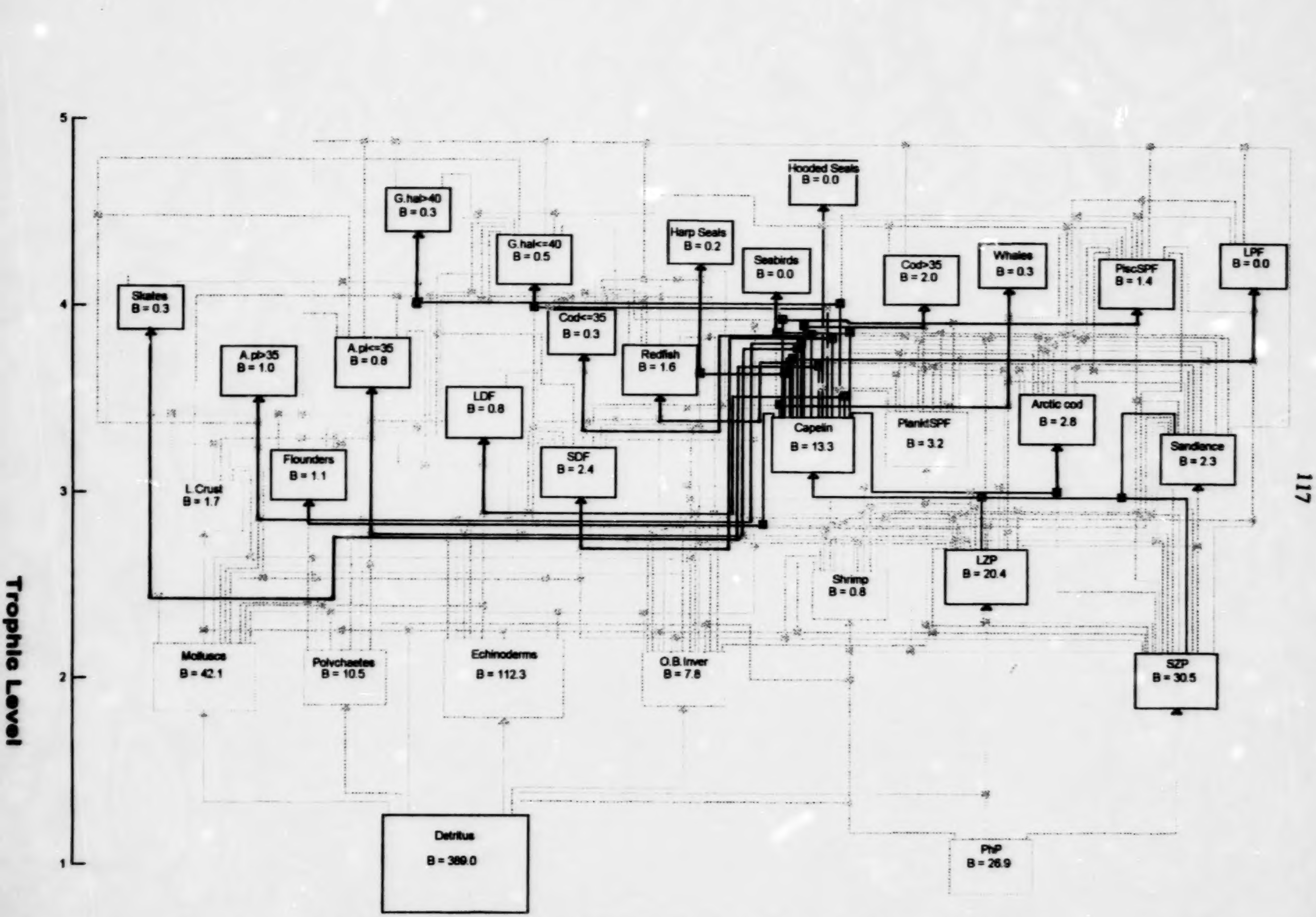
Trophic Level
5
4
3
2
1
Hooded Seals
B = 0.0
G.hal>40
B = 0.3
Harp Seals
B = 0.2
G.hal<=40
B = 0.5
Seabirds
B = 0.0
Cod>35
B = 2.0
Whales
B = 0.3
PiscSPF
B = 1.4
LPF
B = 0.0
Skates
B = 0.3
Cod<=35
B = 0.3
A.pl>35
B = 1.0
A.pl<=35
B = 0.8
Redfish
B = 1.6
LDF
B = 0.8
Arctic cod
B = 2.8
Capelin
B = 13.3
PlanktSPF
B = 3.2
Sandlance
B = 2.3
Flounders
B = 1.1
SDF
B = 2.4
L.Crust
B = 1.7
LZP
B = 20.4
Shrimp
B = 0.8
Molluscs
B = 42.1
Polychaetes
B = 10.5
Echinoderms
B = 112.3
O.B.Inver
B = 7.8
SZP
B = 30.5
Detritus
B = 389.0
PhP
B = 26.9

Figure 12 Flow diagram of the Newfoundland-Labrador Ecopath model highlighting the role of Capelin.

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Appendix 2. Table 1a. Diet of large (> 35 cm) cod in Division 3L by season and in total.

	3L winter			3L spring				3L summer				3L autumn				3L
								offshore	inshore							total
Common Name	1985	1986	Diet 1	1985	1986	1987	Diet 2	1985	1983	1984	Diet 3	1985	1986	1987	Diet 4	Diet 5
1 Whales	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2 Harp seals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3 Hooded seals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4 Seabirds	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5 Cod > 35 cm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6 Cod <= 35 cm	0.0617	0	0.0309	0.0477	0.0179	0.0048	0.0235	0.0195	0.0003	0	0.0001	0.0325	0.0393	0.0139	0.0286	0.018566
7 Greenland halibut > 40 cm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8 Greenland halibut <= 40 cm	0.0001	0	7E-05	0.0034	0.0057	0.0039	0.0043	0.0109	0	7E-05	4E-05	0.0214	0.0019	0.0053	0.0095	0.003883
9 American plaice > 35 cm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10 American plaice <= 35 cm	0.0624	0.0136	0.038	0.0376	0.0233	0.0156	0.0255	0.0163	0	0.001	0.0005	0.0712	0.0114	0.0171	0.0332	0.021137
11 Flounders	0.0089	0.0004	0.0047	0	0.001	0	0.0003	0	1E-05	0	5E-06	0	0	0	0	0.000998
12 Skates	0	0	0	0.0002	0	0	5E-05	0	0	0	0	0	0	0	0	0.0000
13 Redfish	0.0163	0	0.0081	0.0002	0.0006	0	0.0003	0.0005	0	0	0	0.0039	0.0142	0.0046	0.0076	[illegible]
14 Demersal feeders (misc. large)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15 Demersal feeders (misc. small)	0.1247	0.1112	0.1179	0.0615	0.0587	0.0316	0.0506	0.04	0.0007	0.0002	0.0005	0.1019	0.0707	0.0553	0.0759	0.053043
16 Capelin	0.4655	0.5043	0.4849	0.5976	0.5432	0.5161	0.5523	0.4832	0.9779	0.9398	0.9588	0.3965	0.3071	0.2414	0.315	0.606404
17 Sand lance	0.0347	0.0059	0.0203	0.1225	0.0984	0.2603	0.1604	0.2593	0.0067	0.0337	0.0202	0.1147	0.1674	0.3334	0.2052	0.109162
18 Arctic cod	0.001	0.0159	0.0084	0.0014	0.0004	0.0001	0.0007	0.0021	0	0	0	0.003	0.0031	0.0065	0.0042	0.002869
19 Pelagic feeders (misc. large)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20 Pisc. Pelagic feeders (misc. small)	0.0038	0.0008	0.0023	1E-04	8E-05	0.0005	0.0002	0.001	0.0001	0.0017	0.0009	0.0015	0.0003	0.0009	0.0009	0.001057
21 Plankt. Pelagic feeders (misc. small	0.0113	0.0023	0.0068	0.0003	0.0002	0.0014	0.0006	0.0029	0.0003	0.0052	0.0028	0.0046	0.0008	0.0028	0.0027	0.003171
22 Shrimp	0.0695	0.0939	0.0817	0.0206	0.0179	0.0084	0.0156	0.0146	0.0007	0.0035	0.0021	0.0398	0.06	0.0391	0.0463	0.030831
23 Large Crustaceans (crab, lobster)	0.0496	0.1063	0.0779	0.0591	0.1181	0.0755	0.0842	0.0563	0.0044	0.0069	0.0056	0.1019	0.144	0.137	0.1276	0.065277
24 Echinoderms	0.0046	0.008	0.0063	0.0022	0.0048	0.0021	0.0031	0.0016	0.0059	0.0017	0.0038	0.0062	0.0094	0.0058	0.0071	0.0046
25 Molluscs (benthic)	0.0131	0.052	0.0325	0.03	0.054	0.0305	0.0382	0.0542	0.0004	0.002	0.0012	0.0318	0.0928	0.0488	0.0578	0.031466
26 Polychaetes	0.009	0.0272	0.0181	0.0032	0.0073	0.003	0.0045	0.0066	0.0002	0.0006	0.0004	0.0125	0.0127	0.0118	0.0124	0.007777
27 Benthic invertebrates (other)	0.0485	0.0233	0.0359	0.0105	0.0137	0.0148	0.013	0.024	0.0021	0.0014	0.0017	0.02	0.0323	0.031	0.0278	0.018252
28 Zooplankton (large)	0.0152	0.0349	0.025	0.0021	0.0347	0.0313	0.0227	0.007	0.0003	0.0022	0.0012	0.0397	0.0325	0.0455	0.0392	0.0185
29 Zooplankton (small)	0.0001	0.0000	0.0000	0.0000	0.0000	0	0.0000	0	0.0000	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
30 Phytoplankton	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31 Detritus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
No. of stomachs	1289	589		1843	2898	2413		1057	246	1019		1529	1025	1034		

Diet 1. Division 3L winter diet. Average of 1985 and 1986. Demersal feeders (large) are considered to be juveniles and classified as demersal feeders (small).

Diet 2. Division 3L spring diet. Average of 1985, 1986 and 1987. Demersal feeders (large) are considered to be juveniles and classified as demersal feeders (small)

Diet 3. Division 3L summer inshore diet. Average of 1983 and 1984. Demersal feeders (large) are considered to be juveniles and classified as demersal feeders (small)

Diet 4. Division 3L autumn diet. Average of 1985, 1986 and 1987. Demersal feeders (large) are considered to be juveniles and classified as demersal feeders (small)

Diet 5. Division 3L total diet. The winter, spring, summer offshore, summer inshore and autumn diets are given weightings of 0.2, 0.2, 0.1, 0.3, and 0.2.

This reflects the following weightings for population size (first number) and feeding rate (second number): (1*1), (1*1), (0.5*1), (0.5*3), (1*1).

The summer inshore diet is given a weighting 3 times the offshore diets because of higher stomach fullness and possibly higher temperature.

NB For all diets, the two small pelagic groups were originally one. Here they are split on the assumption that 75% are planktivorous feeders and 25% are piscivorous feeders.

Appendix 2. Table 1b. Diet of large (> 35 cm) cod in divisions 2J3K, 3NO and 2J3KLNO combined.

	summer inshore	2J3K autumn				2J+3K total	3NO spring				2J3K total	3L total	3NO total	2J3KLNO total
Common Name	Diet 3	1985	1986	1987	Diet 6	Diet 7	1985	1986	1987	Diet 8	(Diet 7)	(Diet 5)	(Diet 8)	Diet 9
1 Whales	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2 Harp seals	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3 Hooded seals	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4 Seabirds	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5 Cod > 35 cm	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6 Cod <= 35 cm	0.0001	0.0195	0.0236	0.0232	0.0221	0.0136	0.0200	0.0422	0.0380	0.0334	0.0136	0.0186	0.0334	0.0177
7 Greenland halibut > 40 cm	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8 Greenland halibut <= 40 cm	0.0000	0.0209	0.0085	0.0083	0.0126	0.0078	0.0000	0.0015	0.0000	0.0005	0.0078	0.0039	0.0005	0.0057
9 American plaice > 35 cm	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10 American plaice <= 35 cm	0.0005	0.0015	0.0051	0.0244	0.0103	0.0066	0.0401	0.0649	0.0599	0.0550	0.0066	0.0211	0.0550	0.0171
11 Flounders	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0048	0.0134	0.0000	0.0061	0.0000	0.0010	0.0061	0.0011
12 Skates	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0046	0.0000	0.0015	0.0000	0.0000	0.0015	0.0002
13 Redfish	0.0000	0.0510	0.0020	0.0051	0.0194	0.0120	0.0060	0.0083	0.0012	0.0052	0.0120	0.0032	0.0052	0.0066
14 Demersal feeders (misc. large)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
15 Demersal feeders (misc. small)	0.0005	0.0300	0.0743	0.0532	0.0525	0.0327	0.0784	0.0213	0.0268	0.0422	0.0327	0.0530	0.0422	0.0399
16 Capelin	0.9586	0.5229	0.6460	0.5582	0.5757	0.7213	0.0795	0.0260	0.0882	0.0646	0.7213	0.6064	0.0646	0.6026
17 Sand lance	0.0202	0.0003	0.0000	0.0002	0.0002	0.0078	0.5166	0.6606	0.4068	0.5260	0.0078	0.1092	0.5280	0.1048
18 Arctic cod	0.0000	0.0850	0.0567	0.0329	0.0582	0.0361	0.0000	0.0000	0.0000	0.0000	0.0361	0.0029	0.0000	0.0218
19 Pelagic feeders (misc. large)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
20 Pisc. Pelagic feeders (misc. small)	0.0009	0.0028	0.0023	0.0018	0.0023	0.0018	0.0000	0.0002	0.0000	0.0001	0.0018	0.0011	0.0001	0.0013
21 Plankt. Pelagic feeders (misc. small)	0.0028	0.0084	0.0069	0.0053	0.0069	0.0053	0.0000	0.0005	0.0001	0.0002	0.0053	0.0032	0.0002	0.0040
22 Shrimp	0.0021	0.0752	0.0705	0.0818	0.0759	0.0478	0.0013	0.0010	0.0043	0.0022	0.0478	0.0308	0.0022	0.0370
23 Large Crustaceans (crab, lobster)	0.0056	0.0295	0.0499	0.0563	0.0452	0.0302	0.0963	0.0661	0.1154	0.0926	0.0302	0.0653	0.0926	0.0485
24 Echinoderms	0.0038	0.0022	0.0020	0.0024	0.0022	0.0028	0.0094	0.0066	0.0148	0.0103	0.0028	0.0046	0.0103	0.0043
25 Molluscs (benthic)	0.0012	0.0022	0.0010	0.0016	0.0016	0.0014	0.1105	0.0629	0.1249	0.0994	0.0014	0.0315	0.0994	0.0229
26 Polychaetes	0.0004	0.0041	0.0022	0.0063	0.0042	0.0028	0.0330	0.0084	0.0067	0.0160	0.0028	0.0078	0.0160	0.0059
27 Benthic invertebrates (other)	0.0017	0.0109	0.0076	0.0122	0.0102	0.0070	0.0039	0.0024	0.0096	0.0053	0.0070	0.0183	0.0053	0.0100
28 Zooplankton (large)	0.0012	0.1337	0.0411	0.1268	0.1005	0.0628	0.0002	0.0092	0.1032	0.0375	0.0628	0.0185	0.0375	0.0466
29 Zooplankton (small)	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
30 Phytoplankton	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
31 Detritus	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
No. of stomachs		2,024	1,768	1,924			925	1,091	1,572					

Diet 3. From Table 1a.

Diet 6. Division 2J3K autumn diet. Average of 1985, 1986 and 1987. Demersal feeders (large) are considered to be juveniles and classified as demersal feeders (small).

Diet 7. Division 2J3K total diet. The summer inshore and autumn diets are given weightings of 0.38 and 0.62.

This reflects the following weightings for population size (first number) and feeding rate (second number) for the winter, spring, summer offshore, summer inshore and autumn: (1*0), (1*1), (0.5*1), (0.5*3), (1*1).

It is assumed for simplicity that these cod do not feed in the winter (Lilly 1987) and that the autumn diet is also appropriate for spring and summer offshore.

Diet 8. Division 3NO spring diet. It is assumed that this diet is appropriate for all seasons.Average of 1985, 1986 and 1987. Demersal feeders (large) are considered to be juveniles and classified as demersal feeders (small)

Diet 9. Average of 2J3K, 3L, and 3NO diets, weighted by population sizes. The weightings are 0.58, 0.29, and 0.13. This is based on 0.87 of the average biomass being in 2J3KL, and the assumption that 0.33 of the 2J3KL biomass is in 3L.

NB For all diets, the two small pelagic groups were originally one. Here they are split on the assumption that 75% of small pelagics in the diet are planktivorous feeders and 25% are piscivorous feeders.

Appendix 2. Table 2a. Diet of small (<= 35 cm) cod in Division 3L by season and in total.

	3L winter			3L spring				3L summer		3L autumn				3L
								offshore	inshore					total
Common Name	1985	1986	Diet 1	1985	1986	1987	Diet 2	1985	Diet 3	1985	1986	1987	Diet 4	Diet 5
1 Whales	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2 Harp seals	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3 Hooded seals	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4 Seabirds	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5 Cod > 35 cm	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6 Cod <= 35 cm	0.0035	0.0000	0.0017	0.0000	0.0000	0.0000	0.0000	0.0000	0.0142	0.0000	0.0000	0.0362	0.0121	0.0088
7 Greenland halibut > 40 cm	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8 Greenland halibut <= 40 cm	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0094	0.0000	0.0031	0.0004
9 American plaice > 35 cm	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10 American plaice <= 35 cm	0.0009	0.0003	0.0006	0.0002	0.0000	0.0036	0.0013	0.0005	0.0000	0.0071	0.0016	0.0068	0.0052	0.0009
11 Flounders	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
12 Skates	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
13 Redfish	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0050	0.0017	0.0002
14 Demersal feeders (misc. large)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
15 Demersal feeders (misc. small)	0.0191	0.0509	0.0350	0.0101	0.0022	0.0007	0.0043	0.0083	0.0115	0.0536	0.0340	0.0264	0.0380	0.0165
16 Capelin	0.5730	0.4442	0.5086	0.6848	0.6573	0.4742	0.6054	0.6978	0.3778	0.4806	0.4468	0.4828	0.4701	0.4741
17 Sand lance	0.0539	0.0166	0.0352	0.0213	0.0193	0.0227	0.0211	0.0399	0.0107	0.0190	0.0332	0.1467	0.0663	0.0257
18 Arctic cod	0.0022	0.0000	0.0011	0.0104	0.0000	0.0000	0.0035	0.0000	0.0000	0.0000	0.0167	0.0000	0.0056	0.0013
19 Pelagic feeders (misc. large)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
20 Pisc. Pelagic feeders (misc. small)	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0102	0.0023	0.0000	0.0000	0.0008	0.0052
21 Plankt. Pelagic feeders (misc. sma	0.0000	0.0000	0.0000	0.0000	0.0004	0.0000	0.0001	0.0000	0.0305	0.0069	0.0000	0.0000	0.0023	0.0156
22 Shrimp	0.1639	0.2151	0.1895	0.0802	0.0559	0.0654	0.0671	0.0647	0.0024	0.1504	0.1376	0.1110	0.1330	0.0580
23 Large Crustaceans (crab, lobster)	0.0100	0.0219	0.0160	0.0684	0.0786	0.0885	0.0785	0.0125	0.0040	0.0104	0.0058	0.0081	0.0081	0.0164
24 Echinoderms	0.0004	0.0000	0.0002	0.0004	0.0000	0.0008	0.0004	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002
25 Molluscs (benthic)	0.0104	0.0091	0.0098	0.0137	0.0078	0.0147	0.0121	0.0225	0.0006	0.0149	0.0015	0.0118	0.0094	0.0070
26 Polychaetes	0.0401	0.0441	0.0421	0.0221	0.0239	0.0118	0.0193	0.0158	0.0065	0.0471	0.0511	0.0380	0.0454	0.0186
27 Benthic invertebrates (other)	0.0585	0.0917	0.0751	0.0548	0.0512	0.1142	0.0734	0.0885	0.2589	0.0921	0.0802	0.0869	0.0864	0.1699
28 Zooplankton (large)	0.0632	0.1059	0.0845	0.0324	0.1033	0.2032	0.1129	0.0495	0.2727	0.1156	0.1823	0.0401	0.1127	0.1813
29 Zooplankton (small)	0.0010	0.0002	0.0006	0.0013	0.0001	0.0003	0.0006	0.0000	0.0000	0.0001	0.0000	0.0001	0.0001	0.0002
30 Phytoplankton	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
31 Detritus	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
No. of stomachs	592	262		653	492	274		387	8,240	417	170	239		

Diet 1. Division 3L winter diet. Average of 1985 and 1986. Demersal feeders (large) are considered to be juveniles and classified as demersal feeders (small).

Diet 2. Division 3L spring diet. Average of 1985, 1986 and 1987. Demersal feeders (large) are considered to be juveniles and classified as demersal feeders (small).

Diet 3. Division 3L summer inshore diet. Derived from frequency of occurrence data in 1992-1994. See text for details. Demersal feeders (large) are considered to be juveniles and classified as demersal feeders (small).

Diet 4. Division 3L autumn diet. Average of 1985, 1986 and 1987. Demersal feeders (large) are considered to be juveniles and classified as demersal feeders (small).

Diet 5. Division 3L total diet. The winter, spring, summer offshore, summer inshore and autumn diets are given weightings of 0.125, 0.125, 0.125, 0.5 and 0.125.
This reflects the following weightings for population size (first number) and feeding rate (second number) for the offshore in winter, spring, summer and autumn
and the inshore for winter, spring, summer and autumn: (0.5*1), (0.5*1), (0.5*1), (0.5*1), (0.5*0), (0.5*1), (0.5*2), (0.5*1).
It is assumed that the inshore cod do not feed in winter and that the summer inshore diet is applicable for spring inshore and autumn inshore.

NB For all diets, the two small pelagic groups were originally one. Here they are split on the assumption that 75% are planktivorous feeders and 25% are piscivorous feeders.

Appendix 2. Table 2b. Diet of small (<= 35 cm) cod in divisions 2J3K, 3NO and 2J3KLNO combined.

Common Name	Diet 3	2J3K autumn				2J3K total	3NO spring				2J3K total	3L total	3NO total	2J3KLNO total
		1985	1986	1987	Diet 6	Diet 7	1985	1986	1987	Diet 8	(Diet 7)	(Diet 5)	(Diet 8)	Diet 9
1 Whales	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2 Harp seals	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3 Hooded seals	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4 Seabirds	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5 Cod > 35 cm	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6 Cod <= 35 cm	0.0142	0.0000	0.0000	0.0000	0.0000	0.0054	0.0000	0.0181	0.0000	0.0060	0.0054	0.0088	0.0060	0.0065
7 Greenland halibut > 40 cm	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8 Greenland halibut <= 40 cm	0.0000	0.0129	0.0041	0.0000	0.0057	0.0035	0.0000	0.0000	0.0000	0.0000	0.0035	0.0004	0.0000	0.0023
9 American plaice > 35 cm	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10 American plaice <= 35 cm	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0009	0.0000	0.0003
11 Flounders	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
12 Skates	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
13 Redfish	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0001
14 Demersal feeders (misc. large)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
15 Demersal feeders (misc. small)	0.0115	0.0108	0.0294	0.0790	0.0397	0.0290	0.0032	0.0121	0.0219	0.0124	0.0290	0.0165	0.0124	0.0239
16 Capelin	0.3778	0.5753	0.4126	0.4383	0.4754	0.4383	0.1819	0.1580	0.1292	0.1563	0.4383	0.4741	0.1563	0.4297
17 Sand lance	0.0107	0.0000	0.0000	0.0000	0.0000	0.0041	0.4524	0.2629	0.1585	0.2913	0.0041	0.0257	0.2913	0.0309
18 Arctic cod	0.0000	0.1240	0.0764	0.0475	0.0626	0.0512	0.0000	0.0000	0.0000	0.0000	0.0512	0.0013	0.0000	0.0322
19 Pelagic feeders (misc. large)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
20 Pisc. Pelagic feeders (misc. small)	0.0102	0.0011	0.0010	0.0017	0.0012	0.0046	0.0000	0.0035	0.0006	0.0014	0.0046	0.0052	0.0014	0.0046
21 Plankt. Pelagic feeders (misc. small)	0.0305	0.0032	0.0029	0.0051	0.0037	0.0139	0.0000	0.0106	0.0019	0.0042	0.0139	0.0156	0.0042	0.0137
22 Shrimp	0.0024	0.0751	0.2028	0.1770	0.1516	0.0949	0.0036	0.0398	0.0373	0.0269	0.0949	0.0580	0.0269	0.0787
23 Large Crustaceans (crab, lobster)	0.0040	0.0011	0.0056	0.0177	0.0081	0.0065	0.1404	0.2746	0.1465	0.1871	0.0065	0.0164	0.1871	0.0222
24 Echinoderms	0.0003	0.0000	0.0003	0.0000	0.0001	0.0002	0.0000	0.0017	0.0000	0.0006	0.0002	0.0002	0.0006	0.0002
25 Molluscs (benthic)	0.0006	0.0018	0.0011	0.0005	0.0012	0.0009	0.1380	0.0049	0.0113	0.0514	0.0009	0.0070	0.0514	0.0064
26 Polychaetes	0.0065	0.0094	0.0323	0.0212	0.0209	0.0155	0.0222	0.0239	0.0254	0.0238	0.0155	0.0186	0.0238	0.0170
27 Benthic invertebrates (other)	0.2589	0.0238	0.0737	0.0717	0.0564	0.1333	0.0342	0.0546	0.0558	0.0482	0.1333	0.1699	0.0482	0.1387
28 Zooplankton (large)	0.2727	0.1616	0.1573	0.1398	0.1529	0.1984	0.0242	0.1354	0.4116	0.1904	0.1984	0.1813	0.1904	0.1926
29 Zooplankton (small)	0.0000	0.0002	0.0006	0.0005	0.0004	0.0003	0.0000	0.0000	0.0000	0.0000	0.0003	0.0002	0.0000	0.0002
30 Phytoplankton	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
31 Detritus	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
No. of stomachs		411	353	238			284	163	320					

Diet 3. From Table 2a.

Diet 6. Division 2J3K autumn diet. Average of 1985, 1986 and 1987. Demersal feeders (large) are considered to be juveniles and classified as demersal feeders (small).

Diet 7. Division 2J3K total diet. The offshore autumn and inshore diets are given weightings of 0.62 and 0.38.
This reflects the following weightings for population size (first number) and feeding rate (second number) for the offshore in winter, spring, summer and autumn and the inshore for winter, spring, summer and autumn: (0.5*0), (0.5*1), (0.25*1), (0.5*1), (0.5*0), (0.5*1), (0.75*2), (0.5*1).
It is assumed that there is no feeding in winter, that the summer inshore diet is applicable for spring inshore and autumn inshore. and that the offshore autumn diet is also appropriate for offshore spring and offshore summer.

Diet 8. Division 3NO spring diet. It is assumed that this diet is appropriate for all seasons. Demersal feeders (large) are considered to be juveniles and classified as demersal feeders (small).

Diet 9. Average of 2J3K, 3L, and 3NO diets, weighted by population sizes. The weightings are 0.62, 0.31, and 0.07. This is based on 0.93 of the average biomass being in 2J3KL, and the assumption that 0.33 of the 2J3KL biomass is in 3L.

NB For all diets, the two small pelagic groups were originally one. Here they are split on the assumption that 75% are planktivorous feeders and 25% are piscivorous feeders.

Appendix 2. Table 3. Diet of large (> 40 cm) Greenland halibut in Divisions 2J3K, 3L, and 2J3KL together.

	2J3K autumn						3L 1985				3L total	2J3KL total
Common Name	1985	1986	1987	Diet 1	Diet 1.1	Diet 1.2	winter	spring	summer	autumn	Diet 2	Diet 3
1 Whales	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2 Harp seals	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3 Hooded seals	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4 Seabirds	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5 Cod > 35 cm	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6 Cod <= 35 cm	0.0695	0.1166	0.0646	0.0836	0.0695	0.081	0.0548	0.0432	0.0000	0.0215	0.0299	0.0764
7 Greenland halibut > 40 cm	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8 Greenland halibut <= 40 cm	0.1176	0.1111	0.2910	0.1732	0.1176	0.137	0.0485	0.0000	0.0521	0.0011	0.0254	0.1269
9 American plaice > 35 cm	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10 American plaice <= 35 cm	0.0139	0.0000	0.0000	0.0046	0.0000	0	0.0000	0.0000	0.0424	0.0000	0.0106	0.0010
11 Flounders	0.0023	0.0000	0.0048	0.0024	0.0023	0.003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0024
12 Skates	0.0037	0.0000	0.0008	0.0015	0.0008	0.001	0.0000	0.0000	0.0044	0.0000	0.0011	0.0010
13 Redfish	0.2146	0.3718	0.2380	0.2748	0.2380	0.277	0.1412	0.0116	0.0064	0.0312	0.0476	0.2565
14 Demersal feeders (misc. large)	0.0000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
15 Demersal feeders (misc. small)	0.1001	0.0632	0.0743	0.0792	0.0743	0.087	0.2576	0.0118	0.0376	0.0104	0.0793	0.0859
16 Capelin	0.4100	0.2976	0.2589	0.3222	0.2976	0.347	0.3956	0.8592	0.8314	0.9092	0.7489	0.3828
17 Sand lance	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
18 Arctic cod	0.0333	0.0030	0.0246	0.0203	0.0246	0.029	0.0066	0.0239	0.0002	0.0000	0.0077	0.0267
19 Pelagic feeders (misc. large)	0.0055	0.0004	0.0018	0.0025	0.0018	0.002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0019
20 Pisc. Pelagic feeders (misc. small)	0.0035	0.0044	0.0063	0.0047	0.0044	0.0051	0.0209	0.0096	0.0020	0.0060	0.0096	0.0055
21 Plankt. Pelagic feeders (misc. small)	0.0105	0.0131	0.0190	0.0142	0.0131	0.0153	0.0627	0.0287	0.0061	0.0180	0.0289	0.0165
22 Shrimp	0.0113	0.0124	0.0119	0.0119	0.0119	0.014	0.0103	0.0090	0.0097	0.0016	0.0077	0.0133
23 Large Crustaceans (crab, lobster)	0.0000	0.0020	0.0000	0.0007	0.0000	0	0.0000	0.0004	0.0000	0.0000	0.0001	0.0000
24 Echinoderms	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
25 Molluscs (benthic)	0.0000	0.0012	0.0000	0.0004	0.0000	0.000	0.0000	0.0000	0.0006	0.0000	0.0002	0.0000
26 Polychaetes	0.0000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
27 Benthic invertebrates (other)	0.0004	0.0004	0.0025	0.0011	0.0004	0.001	0.0015	0.0024	0.0044	0.0007	0.0022	0.0007
28 Zooplankton (large)	0.0037	0.0029	0.0014	0.0027	0.0029	0.003	0.0003	0.0001	0.0027	0.0003	0.0009	0.0031
29 Zooplankton (small)	0.0000	0.0000	0.0001	0.0000	0.0000	0.000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
30 Phytoplankton	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
31 Detritus	0.0000	0.0000	0.0000	0.0000	0.0000	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
No. of stomachs	2392	1460	1469				268	257	434	332		

Diet 1. Division 2J3K autumn diet. Average of 1985, 1986 and 1987. Demersal feeders (large) are considered to be juveniles and classified as demersal feeders (small).

Diet 1.1 Division 2J3K autumn diet expressed as the median of 1985, 1986 and 1987.

Diet 1.2 Diet 1.1 normalised

Diet 2. Division 3L diet. Average of the four seasons. Sampling went only to 366 m. Demersal feeders (large) are considered to be juveniles and classified as demersal feeders (small).

Diet 3. Division 2J3KL diet. The 2J3K autumn diet is assumed to be appropriate for all seasons. The 2J3K autumn diet (Diet 1.2) and the 3L annual diet (Diet 2) are averaged with weightings of 0.91 and 0.09 to reflect the relative biomasses in 2J3K and 3L as determined during autumn research surveys (Fig. 14 of Bowering and Brodie, 1995).

NB For all diets, the two small pelagic groups were originally one. Here they are split on the assumption that 75% are planktivorous feeders and 25% are piscivorous feeders.

Appendix 2. Table 4. Diet of small (<= 40 cm) Greenland halibut in Divisions 2J3K, 3L, and 2J3KL together.

	2J3K autumn				3L 1985				3L total	2J3KL total
Common Name	1985	1986	1987	Diet 1	winter	spring	summer	autumn	Diet 2	Diet 3
1 Whales	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2 Harp seals	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3 Hooded seals	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4 Seabirds	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5 Cod > 35 cm	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6 Cod <= 35 cm	0.0085	0.0149	0.0000	0.0078	0.0000	0.0733	0.0000	0.0000	0.0183	0.0087
7 Greenland halibut > 40 cm	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8 Greenland halibut <= 40 cm	0.0041	0.0127	0.0013	0.0060	0.0000	0.0000	0.0000	0.0000	0.0000	0.0055
9 American plaice > 35 cm	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10 American plaice <= 35 cm	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
11 Flounders	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
12 Skates	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
13 Redfish	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
14 Demersal feeders (misc. large)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
15 Demersal feeders (misc. small)	0.0005	0.0155	0.0087	0.0082	0.0000	0.0026	0.0000	0.0000	0.0007	0.0076
16 Capelin	0.8354	0.8279	0.8048	0.8227	0.9451	0.9030	0.9749	0.9604	0.9458	0.8338
17 Sand lance	0.0000	0.0000	0.0000	0.0000	0.0089	0.0000	0.0000	0.0000	0.0022	0.0002
18 Arctic cod	0.0916	0.0303	0.0404	0.0541	0.0078	0.0124	0.0035	0.0000	0.0059	0.0498
19 Pelagic feeders (misc. large)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
20 Pisc. Pelagic feeders (misc. small)	0.0077	0.0114	0.0125	0.0105	0.0056	0.0000	0.0000	0.0079	0.0034	0.0099
21 Plankt. Pelagic feeders (misc. sma	0.0231	0.0341	0.0376	0.0316	0.0168	0.0000	0.0000	0.0238	0.0101	0.0297
22 Shrimp	0.0182	0.0308	0.0223	0.0238	0.0050	0.0070	0.0093	0.0042	0.0064	0.0222
23 Large Crustaceans (crab, lobster)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
24 Echinoderms	0.0000	0.0000	0.0000	0.0000	0.0032	0.0000	0.0000	0.0000	0.0008	0.0001
25 Molluscs (benthic)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
26 Polychaetes	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000
27 Benthic invertebrates (other)	0.0030	0.0060	0.0017	0.0036	0.0007	0.0004	0.0066	0.0030	0.0027	0.0035
28 Zooplankton (large)	0.0079	0.0164	0.0707	0.0317	0.0068	0.0014	0.0057	0.0008	0.0037	0.0291
29 Zooplankton (small)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
30 Phytoplankton	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
31 Detritus	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
No. of stomachs	1865	1134	1407		219	242	319	200		

Diet 1. Division 2J3K autumn diet. Average of 1985, 1986 and 1987. Demersal feeders (large) are considered to be juveniles and classified as demersal feeders (small).

Diet 2. Division 3L diet. Average of the four seasons. Sampling went only to 366 m.

Diet 3. Division 2J3KL diet. The 2J3K autumn diet is assumed to be appropriate for all seasons. The 2J3K autumn diet (Diet 1) and the 3L annual diet (Diet 2) are averaged with weightings of 0.91 and 0.09 to reflect the relative biomasses in 2J3K and 3L as determined during autumn research surveys (Fig. 14 of Bowering and Brodie, 1995).

NB For all diets, the two small pelagic groups were originally one. Here they are split on the assumption that 75% of small pelagics in the diet are planktivorous feeders and 25% are piscivorous feeders.

Appendix 2. Table 5a. Diet of large (> 35 cm) American plaice in Divisions 2J3K and 3L.

	2J3K					3L				
	2J autumn			3K aut.	total	3L 1985				total
Common Name	1977	1978	Diet 1	pl3k78au	Diet 2	winter	spring	summer	autumn	Diet 3
1 Whales	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2 Harp seals	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3 Hooded seals	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4 Seabirds	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5 Cod > 35 cm	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6 Cod <= 35 cm	0.0000	0.0024	0.0012	0.0000	0.0006	0.0000	0.0000	0.0000	0.0000	0.0000
7 Greenland halibut > 40 cm	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8 Greenland halibut <= 40 cm	0.1558	0.0065	0.0812	0.0000	0.0406	0.0000	0.0000	0.0011	0.0007	0.0005
9 American plaice > 35 cm	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10 American plaice <= 35 cm	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0063	0.0017
11 Flounders	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0006	0.0002
12 Skates	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
13 Redfish	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
14 Demersal feeders (misc. large)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
15 Demersal feeders (misc. small)	0.0377	0.0094	0.0235	0.0000	0.0118	0.0352	0.0034	0.0024	0.0053	0.0090
16 Capelin	0.6729	0.0000	0.3364	0.0000	0.1682	0.4596	0.4141	0.5446	0.4969	0.4872
17 Sand lance	0.0000	0.0000	0.0000	0.0000	0.0000	0.0849	0.1430	0.1367	0.0126	0.0959
18 Arctic cod	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0042	0.0011
19 Pelagic feeders (misc. large)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
20 Pisc. Pelagic feeders (misc. small	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004	0.0000	0.0001
21 Plankt. Pelagic feeders (misc. sm	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0011	0.0000	0.0004
22 Shrimp	0.0046	0.0000	0.0023	0.0000	0.0012	0.0104	0.0007	0.0023	0.0077	0.0048
23 Large Crustaceans (crab, lobster)	0.0000	0.0007	0.0003	0.0000	0.0002	0.0160	0.1838	0.0124	0.0018	0.0496
24 Echinoderms	0.0888	0.5045	0.2966	0.6654	0.4310	0.3118	0.1509	0.1995	0.3175	0.2393
25 Molluscs (benthic)	0.0000	0.1441	0.0720	0.0000	0.0360	0.0056	0.0424	0.0614	0.0437	0.0428
26 Polychaetes	0.0206	0.2688	0.1447	0.0059	0.0753	0.0107	0.0028	0.0125	0.0105	0.0094
27 Benthic invertebrates (other)	0.0196	0.0636	0.0416	0.3287	0.1852	0.0483	0.0431	0.0187	0.0562	0.0395
28 Zooplankton (large)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0177	0.0158	0.0089	0.0359	0.0186
29 Zooplankton (small)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
30 Phytoplankton	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
31 Detritus	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
No. of stomachs	60	77		42		1030	2001	1589	1765	

Diet 1. Division 2J autumn diet. Average of 1977 and 1978. Demersal feeders (large) are considered to be juveniles and classified as demersal feeders (small).

Diet 2. Division 2J3K autumn diet. Average of 2J diet (Diet 1) and 3K diet. Demersal feeders (large) are considered to be juveniles and classified as demersal feeders (small).

Diet 3. Division 3L diet. Average of 4 seasons, weighted by 0.17, 0.23, 0.33, 0.27 (winter to autumn). Each weighting is the average of weightings calculated for large and small fish, where the weightings are ratios of the square roots of seasonal average total stomach fullness indices.

Demersal feeders (large) are considered to be juveniles and classified as demersal feeders (small).

The fullness indices were calculated as described in Lilly (1991) and Bowering and Lilly (1992).

NB For all diets, the two small pelagic groups were originally one. Here they are split on the assumption that 75% are planktivorous feeders and 25% are piscivorous feeders

Appendix 2. Table 5b. Diet of large (> 35 cm) American plaice in Divisions 3NO and 2J3KLNO together.

	3NO					2J3K	3L	3NO	2J3KLNO	
	3NO spr	3NO summer			total	total	total	total	total	
Common Name	1984	1985	1986	Diet 4	Diet 5	(Diet 2)	(Diet 3)	(Diet 5)	Diet 6	Diet 7
1 Whales	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2 Harp seals	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3 Hooded seals	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4 Seabirds	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5 Cod > 35 cm	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6 Cod <= 35 cm	0.0000	0.0000	0.0006	0.0003	0.0002	0.0006	0.0000	0.0002	0.0001	0.0001
7 Greenland halibut > 40 cm	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8 Greenland halibut <= 40 cm	0.0000	0.0020	0.0000	0.0010	0.0005	0.0406	0.0005	0.0005	0.0053	0.0010
9 American plaice > 35 cm	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10 American plaice <= 35 cm	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0017	0.0000	0.0009	0.0009
11 Flounders	0.0000	0.0000	0.0016	0.0008	0.0004	0.0000	0.0002	0.0004	0.0002	0.0002
12 Skates	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
13 Redfish	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
14 Demersal feeders (misc. large)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
15 Demersal feeders (misc. small)	0.0005	0.0008	0.0342	0.0175	0.0090	0.0118	0.0090	0.0090	0.0093	0.0094
16 Capelin	0.0924	0.0259	0.0000	0.0129	0.0527	0.1682	0.4872	0.0527	0.2960	0.2973
17 Sand lance	0.3155	0.3640	0.3389	0.3514	0.3334	0.0000	0.0959	0.3334	0.1680	0.1687
18 Arctic cod	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0011	0.0000	0.0006	0.0006
19 Pelagic feeders (misc. large)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
20 Pisc. Pelagic feeders (misc. small	0.0000	0.0000	0.0010	0.0005	0.0003	0.0000	0.0001	0.0003	0.0002	0.0002
21 Plankt. Pelagic feeders (misc. sm	0.0000	0.0000	0.0031	0.0016	0.0008	0.0000	0.0004	0.0008	0.0005	0.0005
22 Shrimp	0.0000	0.0010	0.0012	0.0011	0.0005	0.0012	0.0048	0.0005	0.0028	0.0029
23 Large Crustaceans (crab, lobster)	0.0946	0.0112	0.0061	0.0086	0.0516	0.0002	0.0496	0.0516	0.0444	0.0446
24 Echinoderms	0.3076	0.3102	0.3506	0.3304	0.3190	0.4810	0.2393	0.3190	0.2964	0.2976
25 Molluscs (benthic)	0.1185	0.2276	0.1441	0.1858	0.1522	0.0360	0.0428	0.1522	0.0805	0.0808
26 Polychaetes	0.0075	0.0023	0.0104	0.0063	0.0069	0.0753	0.0094	0.0069	0.0164	0.0165
27 Benthic invertebrates (other)	0.0238	0.0430	0.0786	0.0608	0.0423	0.1852	0.0395	0.0423	0.0579	0.0582
28 Zooplankton (large)	0.0397	0.0121	0.0297	0.0209	0.0303	0.0000	0.0186	0.0303	0.0205	0.0206
29 Zooplankton (small)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
30 Phytoplankton	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
31 Detritus	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
No. of stomachs	1034	637	847							

Diet 4. Division 3NO summer diet. Average of 1985 and 1986. Demersal feeders (large) are considered to be juveniles and classified as demersal feeders (small).

Diet 5. Division 3NO average diet. Average of spring diet and summer diet (Diet 4).

Diet 6. Division 2J3KLNO diet. Average of the 2J3K, 3L and 3NO diets, weighted by 0.12, 0.53 and 0.35, which are the relative biomasses in these areas.

Diet 7. Arbitrary adjustment to Diet 6. The value of 0.0053 for Greenland halibut <= 40 cm seems high. It derives from a very high value (0.1558) in the 2J autumn 1997 sample. The sample size was very small. A high value for Greenland halibut was also recorded for cod stomachs sampled at the same time (Lilly 1984). This value was clearly anomalous compared with other years (Lilly 1984, 1991). For the American plaice diet, the value of Greenland halibut <= 40 cm is reduced to 0.001, and the values for all other boxes are increased proportionally to bring the total to 1.

NB For all diets, the two small pelagic groups were originally one. Here they are split on the assumption that 75% are planktivorous feeders and 25% are piscivorous feeders.

Appendix 2. Table 6a. Diet of small (<= 35 cm) American plaice in Divisions 2J3K and 3L.

	2J3K					3L				
	2J autumn			3K aut.	total	3L 1985				total
Common Name	1977	1978	Diet 1	1978	Diet 2	winter	spring	summer	autumn	Diet 3
1 Whales	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2 Harp seals	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3 Hooded seals	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4 Seabirds	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5 Cod > 35 cm	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6 Cod <= 35 cm	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
7 Greenland halibut > 40 cm	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8 Greenland halibut <= 40 cm	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0144	0.0039
9 American plaice > 35 cm	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10 American plaice <= 35 cm	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0006	0.0221	0.0062
11 Flounders	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
12 Skates	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
13 Redfish	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0061	0.0016
14 Demersal feeders (misc. large)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
15 Demersal feeders (misc. small)	0.0151	0.0315	0.0233	0.0000	0.0117	0.0154	0.0096	0.0041	0.0066	0.0079
16 Capelin	0.0000	0.0000	0.0000	0.0000	0.0000	0.6925	0.4528	0.6885	0.6034	0.6120
17 Sand lance	0.0000	0.0000	0.0000	0.0000	0.0000	0.0402	0.1465	0.0448	0.0078	0.0574
18 Arctic cod	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0056	0.0000	0.0236	0.0077
19 Pelagic feeders (misc. large)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
20 Pisc. Pelagic feeders (misc. small)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
21 Plankt. Pelagic feeders (misc. sma	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
22 Shrimp	0.0000	0.0000	0.0000	0.0000	0.0000	0.0718	0.0094	0.0135	0.0222	0.0248
23 Large Crustaceans (crab, lobster)	0.0152	0.0000	0.0076	0.0000	0.0038	0.0083	0.0620	0.0018	0.0012	0.0166
24 Echinoderms	0.2879	0.1171	0.2025	0.4909	0.3467	0.0289	0.0626	0.0701	0.0816	0.0644
25 Molluscs (benthic)	0.0152	0.0000	0.0076	0.0000	0.0038	0.0041	0.0190	0.0228	0.0086	0.0149
26 Polychaetes	0.3030	0.1577	0.2303	0.3818	0.3061	0.0897	0.0674	0.0655	0.0483	0.0654
27 Benthic invertebrates (other)	0.3636	0.6937	0.5287	0.1273	0.3280	0.0369	0.1529	0.0734	0.0773	0.0865
28 Zooplankton (large)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0122	0.0118	0.0150	0.0768	0.0305
29 Zooplankton (small)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001
30 Phytoplankton	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
31 Detritus	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
No. of stomachs	81	49		48		1003	1670	1249	1737	

Diet 1. Division 2J autumn diet. Average of 1977 and 1978.

Diet 2. Division 2J3K autumn diet. Average of 2J diet (Diet 1) and 3K diet.

Diet 3. Division 3L diet. Average of 4 seasons, weighted by 0.17, 0.23, 0.33, 0.27 (winter to autumn). Each weighting is the average of weightings calculated for large and small fish, where the weightings are ratios of the square roots of seasonal average total stomach fullness indices.

Demersal feeders (large) are considered to be juveniles and classified as demersal feeders (small).

The fullness indices were calculated as described in Lilly (1991) and Bowering and Lilly (1992).

NB For all diets, the two small pelagic groups were originally one. Here they are split on the assumption that 75% are planktivorous feeders and 25% are piscivorous feeders

Appendix 2. Table 6b. Diet of small (<= 35 cm) American plaice in Divisions 3NO and 2J3KLNO together.

	3NO					2J3K	3L	3NO	2J3KLNO
	3NO spr	3NO summer			total	total	total	total	total
Common Name	1984	1985	1986	Diet 4	Diet 5	(Diet 2)	(Diet 3)	(Diet 5)	Diet 6
1 Whales	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2 Harp seals	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3 Hooded seals	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4 Seabirds	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5 Cod > 35 cm	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6 Cod <= 35 cm	0.0000	0.0000	0.0538	0.0269	0.0134	0.0000	0.0000	0.0134	0.0043
7 Greenland halibut > 40 cm	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8 Greenland halibut <= 40 cm	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0039	0.0000	0.0019
9 American plaice > 35 cm	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10 American plaice <= 35 cm	0.0000	0.2119	0.0112	0.1115	0.0558	0.0000	0.0062	0.0558	0.0209
11 Flounders	0.0000	0.0000	0.0980	0.0490	0.0245	0.0000	0.0000	0.0245	0.0079
12 Skates	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
13 Redfish	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0016	0.0000	0.0008
14 Demersal feeders (misc. large)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
15 Demersal feeders (misc. small)	0.0167	0.0786	0.0947	0.0866	0.0517	0.0117	0.0079	0.0517	0.0227
16 Capelin	0.2175	0.0515	0.0000	0.0258	0.1216	0.0000	0.6120	0.1216	0.3334
17 Sand lance	0.1312	0.3728	0.1478	0.2603	0.1958	0.0000	0.0574	0.1958	0.0905
18 Arctic cod	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0077	0.0000	0.0037
19 Pelagic feeders (misc. large)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
20 Pisc. Pelagic feeders (misc. small)	0.0001	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000
21 Plankt. Pelagic feeders (misc. smal	0.0004	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0002	0.0001
22 Shrimp	0.0024	0.0005	0.0041	0.0023	0.0024	0.0000	0.0248	0.0024	0.0127
23 Large Crustaceans (crab, lobster)	0.0705	0.0005	0.0166	0.0086	0.0395	0.0038	0.0166	0.0395	0.0214
24 Echinoderms	0.0591	0.0005	0.0330	0.0167	0.0379	0.3467	0.0644	0.0379	0.1118
25 Molluscs (benthic)	0.0195	0.1554	0.0940	0.1247	0.0721	0.0038	0.0149	0.0721	0.0311
26 Polychaetes	0.0636	0.0192	0.0847	0.0519	0.0577	0.3061	0.0654	0.0577	0.1106
27 Benthic invertebrates (other)	0.0431	0.1001	0.1547	0.1274	0.0852	0.3280	0.0665	0.0852	0.1339
28 Zooplankton (large)	0.3758	0.0091	0.2075	0.1083	0.2420	0.0000	0.0305	0.2420	0.0923
29 Zooplankton (small)	0.0002	0.0000	0.0000	0.0000	0.0001	0.0000	0.0001	0.0001	0.0001
30 Phytoplankton	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
31 Detritus	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
No. of stomachs	506	325	617						

Diet 4. Division 3NO summer diet. Average of 1985 and 1986. Demersal feeders (large) are considered to be juveniles and classified as demersal feeders (small).

Diet 5. Division 3NO average diet. Average of spring diet and summer diet (Diet 4). Demersal feeders (large) are considered to be juveniles and classified as demersal feeders (small).

Diet 6. Division 2J3KLNO diet. Average of the 2J3K, 3L and 3NO diets, weighted by 0.20, 0.48 and 0.32, which are the relative biomasses in these areas.

NB For all diets, the two small pelagic groups were originally one. Here they are split on the assumption that 75% are planktivorous feeders and 25% are piscivorous feeders.

Appendix 2. Table 7a. Diet of flounders (winter flounder).

	Winter flounder					
	Diet 1	Diet 1.1	Diet 1.2	Diet 2	Diet 2.1	Diet 3
1 Whales	0.000	0.000	0.000	0.000	0.000	0.000
2 Harp seals	0.000	0.000	0.000	0.000	0.000	0.000
3 Hooded seals	0.000	0.000	0.000	0.000	0.000	0.000
4 Seabirds	0.000	0.000	0.000	0.000	0.000	0.000
5 Cod > 35 cm	0.000	0.000	0.000	0.000	0.000	0.000
6 Cod <= 35 cm	0.000	0.000	0.000	0.000	0.000	0.000
7 Greenland halibut > 40 cm	0.000	0.000	0.000	0.000	0.000	0.000
8 Greenland halibut <= 40 cm	0.000	0.000	0.000	0.000	0.000	0.000
9 American plaice > 35 cm	0.000	0.000	0.000	0.000	0.000	0.000
10 American plaice <= 35 cm	0.000	0.000	0.000	0.000	0.000	0.000
11 Flounders	0.000	0.000	0.000	0.000	0.000	0.000
12 Skates	0.000	0.000	0.000	0.000	0.000	0.000
13 Redfish	0.000	0.000	0.000	0.000	0.000	0.000
14 Demersal feeders (misc. large)	0.000	0.000	0.000	0.000	0.000	0.000
15 Demersal feeders (misc. small)	0.000	0.000	0.000	0.077	0.118	0.071
16 Capelin	0.000	0.000	0.000	0.000	0.000	0.000
17 Sand lance	0.000	0.000	0.000	0.000	0.000	0.000
18 Arctic cod	0.000	0.000	0.000	0.000	0.000	0.000
19 Pelagic feeders (misc. large)	0.000	0.000	0.000	0.000	0.000	0.000
20 Pisc. Pelagic feeders (misc. small)	0.000	0.000	0.000	0.000	0.000	0.000
21 Plankt. Pelagic feeders (misc. small)	0.000	0.000	0.000	0.000	0.000	0.000
22 Shrimp	0.000	0.000	0.000	0.000	0.000	0.000
23 Large Crustaceans (crab, lobster)	0.000	0.000	0.000	0.000	0.000	0.000
24 Echinoderms	0.097	0.244	0.244	0.005	0.008	0.102
25 Molluscs (benthic)	0.085	0.215	0.215	0.068	0.104	0.149
26 Polychaetes	0.000	0.000	0.000	0.143	0.220	0.132
27 Benthic invertebrates (other)	0.214	0.539	0.541	0.358	0.550	0.546
28 Zooplankton (large)	0.000	0.000	0.000	0.000	0.000	0.000
29 Zooplankton (small)	0.000	0.000	0.000	0.000	0.000	0.000
30 Phytoplankton	0.000	0.000	0.000	0.000	0.000	0.000
31 Detritus	0.000	0.000	0.000	0.000	0.000	0.000
Total	0.396	0.998	1.000	0.651	1.000	

Diet 1 is from Table 1 of Keats (1990). Data (% weight) are from fish collected in June-August 1983 at 5-15 m in Conception Bay, primarily from rocky bottom.

Diet 1 includes benthic fish eggs (0.0697) which make up a portion of the benthic invertebrate (other) catagory.

Diet 1 does not add up to 1.0 because unidentified material including fleshy algae (Total=0.602) was not included.

Diet 1.1 = (Diet 1)*((0.3958+0.602)/0.3958). i.e. the unidentified material (including fleshy algae) is distributed over all the other prey catagories.

Diet 1.2 is Diet 1.1 standardized to 1.0

Diet 2 is from Appendix Table 1 of Kennedy and Steele (1971). Data (% volume) are from fish collected at all seasons in 1962-1963 at 1-2 m in a small inlet in Conception Bay, mainly from muddy sand.

The benthic invertebrates (other) is dominated (0.294 of 0.358) by eggs of fish (mainly capelin). In addition, 0.153 of the stomach contents was fish remains. It is not clear if this is natural food or offal.

As a guess, it is assumed that half of this was natural food, which is assigned to small demersal feeders.

Diet 2.1 is Diet 2 standardized to 1.

Diet 3 is an average of Diets 1.2 and 2.1, with arbitrary weightings of 0.4 and 0.6. The weightings reflect the small sample size and limited seasonal coverage of Diet 1.

Appendix 2. Table 7b. Diet of flounders (yellowtail, witch and all three species combined).

	Yellowtail			Witch	Winter flounder	Flounders
	Diet 4	Diet 4.1	Diet 4.2	Diet 5	(Diet 3)	Diet 6
1 Whales	0.000	0.000	0.000	0.000	0.000	0.000
2 Harp seals	0.000	0.000	0.000	0.000	0.000	0.000
3 Hooded seals	0.000	0.000	0.000	0.000	0.000	0.000
4 Seabirds	0.000	0.000	0.000	0.000	0.000	0.000
5 Cod > 35 cm	0.000	0.000	0.000	0.000	0.000	0.000
6 Cod <= 35 cm	0.000	0.000	0.000	0.000	0.000	0.000
7 Greenland halibut > 40 cm	0.000	0.000	0.000	0.000	0.000	0.000
8 Greenland halibut <= 40 cm	0.000	0.000	0.000	0.000	0.000	0.000
9 American plaice > 35 cm	0.000	0.000	0.000	0.000	0.000	0.000
10 American plaice <= 35 cm	0.000	0.000	0.000	0.000	0.000	0.000
11 Flounders	0.000	0.000	0.000	0.000	0.000	0.000
12 Skates	0.000	0.000	0.000	0.000	0.000	0.000
13 Redfish	0.000	0.000	0.000	0.000	0.000	0.000
14 Demersal feeders (misc. large)	0.000	0.000	0.000	0.000	0.000	0.000
15 Demersal feeders (misc. small)	0.000	0.000	0.000	0.009	0.071	0.007
16 Capelin	0.037	0.038	0.039	0.000	0.000	0.025
17 Sand lance	0.038	0.040	0.040	0.000	0.000	0.025
18 Arctic cod	0.000	0.000	0.000	0.000	0.000	0.000
19 Pelagic feeders (misc. large)	0.000	0.000	0.000	0.000	0.000	0.000
20 Pisc. Pelagic feeders (misc. small)	0.000	0.000	0.000	0.000	0.000	0.000
21 Plankt. Pelagic feeders (misc. small	0.000	0.000	0.000	0.000	0.000	0.000
22 Shrimp	0.000	0.000	0.000	0.021	0.000	0.007
23 Large Crustaceans (crab, lobster)	0.000	0.000	0.000	0.001	0.000	0.000
24 Echinoderms	0.069	0.072	0.073	0.006	0.102	0.053
25 Molluscs (benthic)	0.028	0.029	0.030	0.024	0.149	0.035
26 Polychaetes	0.380	0.395	0.404	0.660	0.132	0.470
27 Benthic invertebrates (other)	0.348	0.362	0.370	0.279	0.546	0.351
28 Zooplankton (large)	0.040	0.042	0.043	0.001	0.000	0.027
29 Zooplankton (small)	0.000	0.000	0.000	0.000	0.000	0.000
30 Phytoplankton	0.000	0.000	0.000	0.000	0.000	0.000
31 Detritus	0.000	0.000	0.000	0.000	0.000	0.000
Total	0.940	0.978	1.000	1.000		1.000

Diet 4 is from Table 2 of Pitt (1976). These % weight data are from 10-49 cm yellowtail collected in 3L and 3N in 1968-1973. Data may have been collected throughout the year as in Pitt (1973).

Diet 4.1 is (Diet 4)*((0.94+0.038)/0.94). i.e. unidentified material and plants, stones etc. were distributed proportionally over all prey catagories.

Diet 4.2 is Diet 4.1 standardized to 1.0

Diet 5 is from Table 4 of Rae (1969). Since the author says that sampling was proportional to the size composition of the catch, the prey volumes were summed across predator size groups prior to calculation of proportions. The crustacea group included some decapods. The proportion of these was estimated from the frequency of occurrence data in Table 5 [(16.6/76.7)*0.199 = 0.043]. Of this, it was assumed that half (i.e. 0.021) was shrimp and 0.001 was large crustacea. The remainer (0.177) was placed in the other benthic invertebrates.

Diet 6 is the average for the three species, weighted by their respective biomasses (0.624 : 0.319 : 0.057).

Appendix 2. Table 8. Diet of thorny skate.

	Diet 1	Diet 1.1	Diet 1.2	Diet 1.3	Diet 1.4
1 Whales	0.000	0.000	0.000	0.000	0.000
2 Harp seals	0.000	0.000	0.000	0.000	0.000
3 Hooded seals	0.000	0.000	0.000	0.000	0.000
4 Seabirds	0.000	0.000	0.000	0.000	0.000
5 Cod > 35 cm	0.000	0.000	0.000	0.000	0.000
6 Cod <= 35 cm	0.041	0.041	0.049	0.062	0.050
7 Greenland halibut > 40 cm	0.000	0.000	0.000	0.000	0.000
8 Greenland halibut <= 40 cm	0.001	0.001	0.001	0.002	0.001
9 American plaice > 35 cm	0.000	0.000	0.000	0.000	0.000
10 American plaice <= 35 cm	0.001	0.001	0.001	0.002	0.001
11 Flounders	0.006	0.006	0.007	0.009	0.007
12 Skates	0.000	0.000	0.000	0.000	0.000
13 Redfish	0.176	0.179	0.216	0.108	0.086
14 Demersal feeders (misc. large)	0.000	0.000	0.000	0.000	0.000
15 Demersal feeders (misc. small)	0.196	0.200	0.240	0.139	0.111
16 Capelin	0.021	0.021	0.026	0.100	0.080
17 Sand lance	0.118	0.120	0.144	0.182	0.145
18 Arctic cod	0.001	0.001	0.001	0.002	0.001
19 Pelagic feeders (misc. large)	0.000	0.000	0.000	0.000	0.000
20 Pisc. Pelagic feeders (misc. small)	0.047	0.048	0.058	0.072	0.058
21 Plankt. Pelagic feeders (misc. small	0.006	0.006	0.007	0.009	0.007
22 Shrimp	0.010	0.010	0.012	0.015	0.022
23 Large Crustaceans (crab, lobster)	0.143	0.143	0.172	0.216	0.311
24 Echinoderms	0.002	0.002	0.002	0.003	0.004
25 Molluscs (benthic)	0.007	0.007	0.008	0.011	0.015
26 Polychaetes	0.037	0.037	0.045	0.056	0.080
27 Benthic invertebrates (other)	0.006	0.006	0.007	0.009	0.013
28 Zooplankton (large)	0.002	0.002	0.002	0.003	0.004
29 Zooplankton (small)	0.000	0.000	0.000	0.001	0.001
30 Phytoplankton	0.000	0.000	0.000	0.000	0.000
31 Detritus	0.000	0.000	0.000	0.000	0.000
Total of above	0.821	0.831	1.0000	0.9996	0.9996
Total of identified fish	0.614		0.751	0.685	0.548

DIET 1 is from Table 2 of Templeman (1982) (the final column, combining all depths (17-740 m) and all sizes of skates (21-102 cm). The stomachs were collected in 1947-1967 from Greenland to Georges Bank but mainly from 3KLNOP. The prey identified as fish offal are not included.
The value of 0.196 for Demersal Feeders (misc. small) comprises the assumed juveniles of the demersal feeders (large) (0.176) and the true demersal feeders (small) (0.020)
DIET 1.1 has the fish categories in DIET 1 adjusted to account for the unidentified fish in the diet (0.011). That is, Diet 1.1 = (Diet 1) *(0.614+0.011)/0.614, but only for the fish portion of the diet.
DIET 1.2 = (Diet 1.1)/ 0.832, to adjust diet to 1.0.
Diet 1.3 has arbitrary adjustments to Diet 1.2. It is thought that the relative abundance of small redfish and haddock was much lower in 1985-1987 than during the period when the stomachs were collected, so the diet proportions for redfish and demersal feeders large are reduced by half. The diet proportion for capelin seems very low, and is raised to 0.1. Zooplankton (small) is assigned 0.001.All other prey categories are adjusted upward proportionally ((Diet 1.2)*0.14/0.544) so that the categories sum to 1.
Diet 1.4 - Diets 1 - 1.3 above are based on the diet data for larger thorny skates which eat more fish than smaller thorny skates which feed mainly on cephalopods, polychaetes and amphipods (Scott and Scott 1988). Other skate species are also less piscivorous than the thorny skate. To allow for this, the proportion of fish in the diet was reduced by 20% and distributed over the inverebrates groups by their relative contribution to the diet.

Appendix 2. Table 9. Diet of redfish.

	Diet 1	Diet 1.1	Diet 1.2	Diet 2
1 Whales			0.000	0.000
2 Harp seals			0.000	0.000
3 Hooded seals			0.000	0.000
4 Seabirds			0.000	0.000
5 Cod > 35 cm			0.000	0.000
6 Cod <= 35 cm		0.007	0.007	0.002
7 Greenland halibut > 40 cm			0.000	0.000
8 Greenland halibut <= 40 cm			0.000	0.000
9 American plaice > 35 cm			0.000	0.000
10 American plaice <= 35 cm			0.000	0.000
11 Flounders			0.000	0.000
12 Skates			0.000	0.000
13 Redfish		0.007	0.007	0.007
14 Demersal feeders (misc. large)			0.000	0.000
15 Demersal feeders (misc. small)			0.000	0.001
16 Capelin		0.007	0.007	0.007
17 Sand lance			0.000	0.004
18 Arctic cod			0.000	0.000
19 Pelagic feeders (misc. large)			0.000	0.000
20 Pisc. Pelagic feeders (misc. small)			0.000	0.000
21 Plankt. Pelagic feeders (misc. smal	0.012	0.233	0.245	0.245
22 Shrimp	0.035		0.035	0.035
23 Large Crustaceans (crab, lobster)			0.000	0.000
24 Echinoderms			0.000	0.000
25 Molluscs (benthic)			0.000	0.000
26 Polychaetes			0.000	0.000
27 Benthic invertebrates (other)			0.000	0.000
28 Zooplankton (large)	0.538		0.538	0.538
29 Zooplankton (small)	0.161		0.161	0.161
30 Phytoplankton			0.000	0.000
31 Detritus			0.000	0.000
				1.000
Total	0.746	0.254	1.000	

Diet 1 is from Tables 1&2 of Lambert (1960). The diet can only be constructed for the entire area sampled which is the waters all around Newfoundland including the Gulf of St. Lawrence. The invertebrate diet was copied directly from Table 2 into Diet 1. It does not sum to 1 because the fish are not included.

Diet 1.1 is the fish diet only. Nine species of fish make up the diet (Table 1). Each fish species is ranked by abundance from 1 to 3. One is very rare, 2 is rare and 3 is common. It is assumed that the relative contribution to stomach contents is 1:3:9. There are a total of 35 abundance rankings distributed among the nine species. Therefore each ranking is = 0.254/35=0.0073. Capelin, cod and redfish are eached ranked with one (i.e. each is 0.007). The other 6 species are mesopelagic and make up 0.232. Diet 1.2 is the sum of Diet 1 and Diet 1.1.

Diet 2 is a modification of Diet 1.2 based partly on guess and partly on Yanulov (1962) and Konchina (1986). The proportion for cod <= 35 cm is reduced from 0.007 to 0.002, and the balance of 0.005 is distributed among sand lance (0.004) and demersal feeders (small) (0.001), which are the juveniles of the demersal feeders (large).

Appendix 2. Table 10a. Diet of wolffish (a component of the large demersal feeders).

	Atlantic wolffish							Spotted	Northern		Average
	Diet 1	Diet 1.1	Diet 2	Diet 2.1	Diet 2.2	Diet 3	Diet 4	Diet 5	Diet 6	Diet 7	Diet 8
1 Whales	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2 Harp seals	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3 Hooded seals	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4 Seabirds	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5 Cod > 35 cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6 Cod <= 35 cm	0.032	0.032	0.000	0.000	0.000	0.000	0.011	0.000	0.000	0.000	0.005
7 Greenland halibut > 40 cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8 Greenland halibut <= 40 cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9 American plaice > 35 cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10 American plaice <= 35 cm	0.000	0.000	0.019	0.021	0.021	0.000	0.007	0.000	0.000	0.000	0.003
11 Flounders	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12 Skates	0.000	0.000	0.000	0.000	0.000	0.007	0.002	0.000	0.000	0.000	0.001
13 Redfish	0.000	0.000	0.120	0.132	0.132	0.163	0.098	0.000	0.000	0.000	0.049
14 Demersal feeders (misc. large)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15 Demersal feeders (misc. small)	0.005	0.005	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.001
16 Capelin	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17 Sand lance	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18 Arctic cod	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19 Pelagic feeders (misc. large)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20 Pisc. Pelagic feeders (misc. small)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
21 Plankt. Pelagic feeders (misc. sma	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22 Shrimp	0.000	0.000	0.000	0.000	0.000	0.025	0.008	0.004	0.028	0.028	0.012
23 Large Crustaceans (crab, lobster)	0.022	0.022	0.121	0.121	0.121	0.000	0.048	0.204	0.000	0.000	0.075
24 Echinoderms	0.764	0.772	0.262	0.262	0.261	0.528	0.520	0.495	0.757	0.657	0.548
25 Molluscs (benthic)	0.118	0.119	0.356	0.356	0.355	0.234	0.236	0.011	0.056	0.056	0.135
26 Polychaetes	0.000	0.000	0.001	0.001	0.001	0.005	0.002	0.008	0.019	0.019	0.008
27 Benthic invertebrates (other)	0.048	0.049	0.111	0.111	0.111	0.038	0.066	0.279	0.140	0.140	0.138
28 Zooplankton (large)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.100	0.025
29 Zooplankton (small)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
30 Phytoplankton	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
31 Detritus	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	0.989		0.990	1.004	1.000						
Total of identified fish			0.139								

Diet 1 is from Table 1 of Keats et al. (1986). Data (% weight) are from fish collected in 1983-1984 at 5-15 m, primarily from hard bottom dominated by sea urchins.
The value for cod is derived from one large cod in one wolffish. Demersal fish eggs are included in the benthic invertebrate (other) category.
Diet 1.1 is Diet 1 adjusted to a total of 1.0
Diet 2 is from Table 2 of Templeman (1984). Data (% volume) are from fish collected in 1946-1966 from West Greenland to the Scotian Shelf.
Diet 2.1 is the unidentified fish (0.014) apportioned over the identified fish.
Diet 2.2 is Diet 2.1 standardized to 1.0.
Diet 3 is from Table 2 of Albikovskaya (1983). Data (fullness indices) were collected in 2J3KL in 1981.
The two sources of data for each Division were averaged, and then the data from the 3 Divisions were averaged and converted to proportions.
Diet 4 is the average of the diets from the three studies of Atlantic wolffish.
Diets 5 and 6 are from Albikovskaya (1983), calculated as described for Diet 3.
Diet 7 is Diet 6 modified to give 0.1 to large zooplankton, since northern wolffish feed on ctenophores and medusae.
Diet 8 is the average for the three species, weighted arbitrarily by 0.5, 0.25 and 0.25.

Appendix 2. Table 10b. Diet of grenadier (a component of the large demersal feeders).

	Roughhead		Roundnose			Common		Average
	Diet 9	Diet 9.1	Diet 10	Diet 10.1	Diet 10.2	Diet 11	Diet 11.1	Diet 12
1 Whales	0.0	0.000	0.000	0.000	0.000	0.0	0.000	0.000
2 Harp seals	0.0	0.000	0.000	0.000	0.000	0.0	0.000	0.000
3 Hooded seals	0.0	0.000	0.000	0.000	0.000	0.0	0.000	0.000
4 Seabirds	0.0	0.000	0.000	0.000	0.000	0.0	0.000	0.000
5 Cod > 35 cm	0.0	0.000	0.000	0.000	0.000	0.0	0.000	0.000
6 Cod <= 35 cm	0.0	0.000	0.000	0.000	0.000	0.0	0.000	0.000
7 Greenland halibut > 40 cm	0.0	0.000	0.000	0.000	0.000	0.0	0.000	0.000
8 Greenland halibut <= 40 cm	0.0	0.000	0.000	0.000	0.000	0.0	0.000	0.000
9 American plaice > 35 cm	0.0	0.000	0.000	0.000	0.000	0.0	0.000	0.000
10 American plaice <= 35 cm	0.1	0.001	0.000	0.000	0.000	0.0	0.000	0.000
11 Flounders	0.0	0.000	0.000	0.000	0.000	0.0	0.000	0.000
12 Skates	0.0	0.000	0.000	0.000	0.000	0.0	0.000	0.000
13 Redfish	0.5	0.004	0.024	0.030	0.036	0.0	0.000	0.016
14 Demersal feeders (misc. large)	0.0	0.000	0.000	0.000	0.000	0.0	0.000	0.000
15 Demersal feeders (misc. small)	0.2	0.002	0.000	0.000	0.000	0.0	0.000	0.001
16 Capelin	9.6	0.081	0.000	0.000	0.000	0.0	0.000	0.032
17 Sand lance	4.7	0.040	0.000	0.000	0.000	0.0	0.000	0.016
18 Arctic cod	0.0	0.000	0.000	0.000	0.000	0.0	0.000	0.000
19 Pelagic feeders (misc. large)	0.0	0.000	0.000	0.000	0.000	0.0	0.000	0.000
20 Pisc. Pelagic feeders (misc. small)	0.0	0.000	0.000	0.000	0.000	0.0	0.000	0.000
21 Plankt. Pelagic feeders (misc. smal	0.7	0.006	0.244	0.300	0.150	0.0	0.000	0.062
22 Shrimp	8.9	0.075	0.387	0.387	0.477	13.3	0.154	0.252
23 Large Crustaceans (crab, lobster)	1.3	0.011	0.000	0.000	0.000	0.0	0.000	0.004
24 Echinoderms	30.6	0.259	0.000	0.000	0.000	7.1	0.082	0.120
25 Molluscs (benthic)	11.7	0.099	0.000	0.000	0.000	9.1	0.105	0.061
26 Polychaetes	19.0	0.161	0.005	0.005	0.006	25.7	0.297	0.126
27 Benthic invertebrates (other)	22.4	0.190	0.057	0.057	0.070	25.8	0.298	0.164
28 Zooplankton (large)	7.2	0.061	0.168	0.168	0.207	5.0	0.058	0.119
29 Zooplankton (small)	1.3	0.011	0.042	0.042	0.052	0.5	0.006	0.026
30 Phytoplankton	0.0	0.000	0.000	0.000	0.000	0.0	0.000	0.000
31 Detritus	0.0	0.000	0.000	0.000	0.000	0.0	0.000	0.000
Total	118.2	1.000	0.927	0.989	0.999	86.5	1.000	1.000

Diet 9 is from Table 7 of Savvatimsky (1989a). Data (% occurrence) are from 11-90 cm fish collected in 1969-1983 in the areas of Baffin Island, Labrador and Newfoundland. The value of 0.2 for the demersal feeders (small) is due to the juvenile large demersal feeders.

Diet 9.1 The frequencies were summed and the frequency for each prey category was expressed as a proportion of the total.

Diet 10 is from Table 3 of Gushchin and Podrazhanskaya (1983). Data (% weight) are provided for various areas. The data here are averages of the values given for southern Labrador, northern Newfoundland and northeastern slope of Grand Bank. It is assumed that the Decapoda are all shrimp.

Diet 10.1 is Diet 1 with the fish components adjusted for the unidentified fish (0.062).

Diet 10.2 It is also assumed that the value for "pelagic feeders small" is much too high, since it is based almost entirely on an extremely high value for myctophids in a sample with a small sample size. The value for this group is arbitrarily reduced to 0.15, and all other groups are adjusted to bring the total to 1.0

Diet 11 is from Table 5 of Savvatimsky (1989b). Data (% occurrence) are from fish collected in 1969 and 1979 in 3LNOP.

Diet 11.1 The frequencies were summed and the frequency for each prey category was expressed as a proportion of the total.

Diet 12 is an average of the diets of the three species, with arbitrary weightings of 0.4, 0.4 and 0.2, based somewhat on relative individual size.

Appendix 2. Table 10c. Diet of white hake and haddock (components of the large demersal feeders).

	white hake		haddock					
	Diet 13	Diet 13.1	Diet 14	Diet 14.1	Diet 15	Diet 15.1	Diet 16	Diet 17
1 Whales	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2 Harp seals	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3 Hooded seals	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4 Seabirds	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5 Cod > 35 cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6 Cod <= 35 cm	0.062	0.090	0.003	0.004	0.003	0.004	0.004	0.004
7 Greenland halibut > 40 cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8 Greenland halibut <= 40 cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9 American plaice > 35 cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10 American plaice <= 35 cm	0.062	0.090	0.020	0.024	0.000	0.000	0.012	0.012
11 Flounders	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12 Skates	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13 Redfish	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14 Demersal feeders (misc. large)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15 Demersal feeders (misc. small)	0.186	0.270	0.005	0.006	0.014	0.017	0.012	0.012
16 Capelin	0.062	0.090	0.000	0.000	0.000	0.000	0.000	0.090
17 Sand lance	0.062	0.090	0.083	0.098	0.000	0.000	0.049	0.049
18 Arctic cod	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19 Pelagic feeders (misc. large)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20 Pisc. Pelagic feeders (misc. small)	0.011	0.016	0.002	0.002	0.000	0.000	0.001	0.001
21 Plankt. Pelagic feeders (misc. sma	0.073	0.106	0.039	0.046	0.129	0.158	0.102	0.012
22 Shrimp	0.027	0.039	0.078	0.092	0.015	0.018	0.055	0.055
23 Large Crustaceans (crab, lobster)	0.010	0.015	0.031	0.037	0.004	0.005	0.021	0.021
24 Echinoderms	0.008	0.012	0.210	0.248	0.299	0.367	0.308	0.308
25 Molluscs (benthic)	0.007	0.010	0.058	0.068	0.031	0.038	0.053	0.053
26 Polychaetes	0.005	0.007	0.168	0.198	0.176	0.216	0.207	0.207
27 Benthic invertebrates (other)	0.000	0.000	0.116	0.137	0.116	0.143	0.140	0.140
28 Zooplankton (large)	0.114	0.165	0.034	0.040	0.027	0.033	0.037	0.037
29 Zooplankton (small)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
30 Phytoplankton	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
31 Detritus	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	0.689	1.000	0.847	1.000	0.814	1.000	1.000	1.000

Diet 13 is from Table 2 of Petrov (1973). Data (% occurrence) are from fish collected in 1969-1972 along the southwest slope of Grand Bank in Division 3O. The frequency of occurrence values for the three months in the table were averaged.

The fish component was assigned equally to the 8 species or groups indicated in the text, viz. cod, haddock, flatfish (assumed to be American plaice), sand lance, capelin, myctophids, grenadiers, and gobies.

The demersal feeders (small) are comprised of 0.124 juvenile demersal feeders (large) and 0.062 demersal feeders (small).

Diet 13.1 The frequencies were summed and the frequency for each prey category was expressed as a proportion of the total.

Diet 14 is from Table 2 of Kohler and Fitzgerald (1969). Data (percentage volume) are from fish collected in Jan.-Apr. 1959-1962 on the Scotian Shelf (Division 4W). The values for each size group and depth range were averaged without weighting. Unidentified material was assigned as seemed appropriate.

The demersal feeders (small) are comprised of 0.002 juvenile demersal feeders (large) and 0.003 demersal feeders (small).

Diet 14.1 The frequencies were summed and the frequency for each prey category was expressed as a proportion of the total.

Diet 15 is from Table 1 of Langton and Bowman (1980). Data (percentage weight) are from fish collected in 1969-1972 from the southwestern Scotian Shelf to south of Georges Bank.

Diet 15.1 The proportions were adjusted to a total of 1.0.

Diet 16 is the average of Diet 14.1 and Diet 15.1.

Diet 17 is the final haddock diet. It is the same as Diet 16, except that 0.09 is removed from small pelagic feeders to capelin to reflect the difference in prey availablity between herring in the Langton and Bowman (1980) study and capelin on the southern Grand Bank (Templeman 1965).

Appendix 2. Table 10d. Diet of zoarcids (a component of the large demersal feeders).

	ocean pout			eelpouts	zoarcids
	Diet 18	Diet 18.1	Diet 18.2	Diet 19	Diet 20
1 Whales	0.000	0.000	0.000	0.000	0.000
2 Harp seals	0.000	0.000	0.000	0.000	0.000
3 Hooded seals	0.000	0.000	0.000	0.000	0.000
4 Seabirds	0.000	0.000	0.000	0.000	0.000
5 Cod > 35 cm	0.000	0.000	0.000	0.000	0.000
6 Cod <= 35 cm	0.000	0.000	0.000	0.000	0.000
7 Greenland halibut > 40 cm	0.000	0.000	0.000	0.000	0.000
8 Greenland halibut <= 40 cm	0.000	0.000	0.000	0.000	0.000
9 American plaice > 35 cm	0.000	0.000	0.000	0.000	0.000
10 American plaice <= 35 cm	0.000	0.000	0.000	0.000	0.000
11 Flounders	0.000	0.000	0.000	0.000	0.000
12 Skates	0.000	0.000	0.000	0.000	0.000
13 Redfish	0.000	0.000	0.000	0.000	0.000
14 Demersal feeders (misc. large)	0.000	0.000	0.000	0.000	0.000
15 Demersal feeders (misc. small)	0.000	0.000	0.000	0.000	0.000
16 Capelin	0.104	0.107	0.107	0.000	0.021
17 Sand lance	0.000	0.000	0.000	0.000	0.000
18 Arctic cod	0.000	0.000	0.000	0.000	0.000
19 Pelagic feeders (misc. large)	0.000	0.000	0.000	0.000	0.000
20 Pisc. Pelagic feeders (misc. small)	0.000	0.000	0.000	0.000	0.000
21 Plankt. Pelagic feeders (misc. small	0.092	0.095	0.095	0.000	0.019
22 Shrimp	0.000	0.000	0.010	0.010	0.010
23 Large Crustaceans (crab, lobster)	0.002	0.002	0.032	0.003	0.009
24 Echinoderms	0.688	0.709	0.509	0.220	0.278
25 Molluscs (benthic)	0.003	0.003	0.063	0.160	0.141
26 Polychaetes	0.000	0.000	0.050	0.160	0.138
27 Benthic invertebrates (other)	0.081	0.084	0.134	0.440	0.379
28 Zooplankton (large)	0.000	0.000	0.000	0.006	0.005
29 Zooplankton (small)	0.000	0.000	0.000	0.001	0.001
30 Phytoplankton	0.000	0.000	0.000	0.000	0.000
31 Detritus	0.000	0.000	0.000	0.000	0.000
Total	0.970			1.000	1.000

Diet 18 is from Table 1 of Keats et al. (1987). Data (% weight) are from fish collected in 1983-1984 at 5-15 m from hard bottom dominated by sea urchins. The benthic invertebrate (other) category is entirely eggs of fish (lumpfish and capelin).

Diet 18.1 is Diet 18 adjusted to a total of 1.0

Diet 18.2 is Diet 18.1 with arbitrary changes to spread the echinoderm value over other groups. An amount of 0.2 is deducted from echinoderms and assigned to shrimp (0.01), large crustaceans (0.03), molluscs (0.06), polychaetes (0.05) and other benthic invertebrates (0.05).

Diet 19 is fictional based on information in Scott and Scott (1988).

Diet 20 is an average of Diet 18.2 and Diet 19, weighted by 0.2 and 0.8 to reflect a guess at relative biomasses.

Appendix 2. Table 10e. Diet of lumpfish, monkfish and Atlantic halibut, and composite diet of the large demersal feeders.

	wolffish	grenadier	white hake	haddock	eelpouts	lumpfish	monkfish	Atlantic halibut	average
	(Diet 8)	(Diet 12)	(Diet 13.1)	(Diet 17)	(Diet 20)	Diet 21	Diet 22	Diet 23	Diet 24
1 Whales	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2 Harp seals	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3 Hooded seals	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4 Seabirds	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5 Cod > 35 cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6 Cod <= 35 cm	0.005	0.000	0.090	0.004	0.000	0.000	0.030	0.039	0.011
7 Greenland halibut > 40 cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8 Greenland halibut <= 40 cm	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.000	0.000
9 American plaice > 35 cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10 American plaice <= 35 cm	0.003	0.000	0.090	0.012	0.000	0.000	0.020	0.136	0.017
11 Flounders	0.000	0.000	0.000	0.000	0.000	0.000	0.040	0.136	0.011
12 Skates	0.001	0.000	0.000	0.000	0.000	0.000	0.010	0.000	0.001
13 Redfish	0.049	0.016	0.000	0.000	0.000	0.000	0.040	0.039	0.016
14 Demersal feeders (misc. large)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15 Demersal feeders (misc. small)	0.001	0.001	0.270	0.012	0.000	0.000	0.200	0.195	0.042
16 Capelin	0.000	0.032	0.090	0.090	0.021	0.020	0.150	0.000	0.039
17 Sand lance	0.000	0.016	0.090	0.049	0.000	0.000	0.210	0.000	0.027
18 Arctic cod	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19 Pelagic feeders (misc. large)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20 Pisc. Pelagic feeders (misc. small)	0.000	0.000	0.016	0.001	0.000	0.000	0.000	0.000	0.001
21 Plankt. Pelagic feeders (misc. sma	0.000	0.062	0.106	0.012	0.019	0.020	0.100	0.000	0.034
22 Shrimp	0.012	0.252	0.039	0.055	0.010	0.010	0.020	0.324	0.090
23 Large Crustaceans (crab, lobster)	0.075	0.004	0.015	0.021	0.009	0.000	0.050	0.094	0.026
24 Echinoderms	0.548	0.120	0.012	0.308	0.278	0.010	0.020	0.008	0.199
25 Molluscs (benthic)	0.135	0.061	0.010	0.053	0.141	0.000	0.020	0.017	0.067
26 Polychaetes	0.008	0.126	0.007	0.207	0.138	0.010	0.020	0.013	0.080
27 Benthic invertebrates (other)	0.138	0.164	0.000	0.140	0.379	0.010	0.060	0.000	0.141
28 Zooplankton (large)	0.025	0.119	0.165	0.037	0.005	0.870	0.005	0.000	0.185
29 Zooplankton (small)	0.000	0.026	0.000	0.000	0.001	0.050	0.000	0.000	0.014
30 Phytoplankton	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
31 Detritus	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Diets 21 and 22 are guesses based on information in Scott and Scott (1988).

The demersal feeders (small) in diet 22 are comprised of 0.06 juvenile demersal feeders (large) and 0.14 demersal feeders (small).

Diet 23 is based on frequency of occurrence data in Kohler (1967). Allocation to major groups is based on observations of stomachs of halibut taken by research otter trawls on the Scotian Shelf (Table 5). Subdivision of the fish component (0.544) is according to the occurrence of fish in stomachs of halibut taken by longliners in the Grand Bank area (Table 8). It is curious that there is no mention of pelagic fish.

Diet 24 is the diet for the large demersal feeders. It is an average of diets 8, 12, 13.1, 17, 20, 21, 22, and 23, with weightings of 0.16, 0.22, 0.06, 0.12, 0.16, 0.16, 0.06 and 0.06.

Appendix 2. Table 11. Diet of small demersal feeders.

	Diet 1
1 Whales	0.000
2 Harp seals	0.000
3 Hooded seals	0.000
4 Seabirds	0.000
5 Cod > 35 cm	0.000
6 Cod <= 35 cm	0.000
7 Greenland halibut > 40 cm	0.000
8 Greenland halibut <= 40 cm	0.000
9 American plaice > 35 cm	0.000
10 American plaice <= 35 cm	0.000
11 Flounders	0.000
12 Skates	0.000
13 Redfish	0.000
14 Demersal feeders (misc. large)	0.000
15 Demersal feeders (misc. small)	0.010
16 Capelin	0.020
17 Sand lance	0.010
18 Arctic cod	0.005
19 Pelagic feeders (misc. large)	0.000
20 Pisc. Pelagic feeders (misc. small)	0.002
21 Plankt. Pelagic feeders (misc. smal	0.003
22 Shrimp	0.020
23 Large Crustaceans (crab, lobster)	0.010
24 Echinoderms	0.100
25 Molluscs (benthic)	0.100
26 Polychaetes	0.200
27 Benthic invertebrates (other)	0.420
28 Zooplankton (large)	0.050
29 Zooplankton (small)	0.050
30 Phytoplankton	0.000
31 Detritus	0.000

Diet 1 is a guess based on information in Scott and Scott (1988).

Appendix 2. Table 12. Diet of capelin.

	spring			autumn	average
	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
1 Whales	0.000	0.000	0.000	0.000	0.000
2 Harp seals	0.000	0.000	0.000	0.000	0.000
3 Hooded seals	0.000	0.000	0.000	0.000	0.000
4 Seabirds	0.000	0.000	0.000	0.000	0.000
5 Cod > 35 cm	0.000	0.000	0.000	0.000	0.000
6 Cod <= 35 cm	0.000	0.000	0.000	0.000	0.000
7 Greenland halibut > 40 cm	0.000	0.000	0.000	0.000	0.000
8 Greenland halibut <= 40 cm	0.000	0.000	0.000	0.000	0.000
9 American plaice > 35 cm	0.000	0.000	0.000	0.000	0.000
10 American plaice <= 35 cm	0.000	0.000	0.000	0.000	0.000
11 Flounders	0.000	0.000	0.000	0.000	0.000
12 Skates	0.000	0.000	0.000	0.000	0.000
13 Redfish	0.000	0.000	0.000	0.000	0.000
14 Demersal feeders (misc. large)	0.000	0.000	0.000	0.000	0.000
15 Demersal feeders (misc. small)	0.000	0.000	0.000	0.000	0.000
16 Capelin	0.028	0.013	0.021	0.000	0.010
17 Sand lance	0.028	0.013	0.021	0.000	0.010
18 Arctic cod	0.000	0.000	0.000	0.000	0.000
19 Pelagic feeders (misc. large)	0.000	0.000	0.000	0.000	0.000
20 Pisc. Pelagic feeders (misc. small)	0.000	0.000	0.000	0.000	0.000
21 Plankt. Pelagic feeders (misc. smal	0.000	0.000	0.000	0.000	0.000
22 Shrimp	0.000	0.000	0.000	0.000	0.000
23 Large Crustaceans (crab, lobster)	0.000	0.000	0.000	0.000	0.000
24 Echinoderms	0.000	0.000	0.000	0.000	0.000
25 Molluscs (benthic)	0.000	0.000	0.000	0.000	0.000
26 Polychaetes	0.000	0.000	0.000	0.000	0.000
27 Benthic invertebrates (other)	0.000	0.000	0.000	0.000	0.000
28 Zooplankton (large)	0.445	0.599	0.522	0.345	0.434
29 Zooplankton (small)	0.499	0.375	0.437	0.655	0.546
30 Phytoplankton	0.000	0.000	0.000	0.000	0.000
31 Detritus	0.000	0.000	0.000	0.000	0.000

Diet 1 is from Table 3 of Gerasimova (1994). Data (% occurrence) are from fish collected in April-May 1987-1990 on Grand Bank. The frequency for each prey type was averaged across the 4 years and 2 maturity stages and expressed as a proportion of the sum of the frequencies for all prey categories. The "fish juvenile" portion was divided evenly between capelin and sand lance.
Diet 2 is from Table 4 of Kovalyov and Kudrin (1973). Data (% occurrence) are from fish collected in March-June 1972 on Grand Bank. The frequency for each prey type was expressed as a proportion of the sum of the frequencies for all prey categories. The "fish larvae" portion was divided evenly between capelin and sand lance.
Diet 3 is an average spring Grand Bank diet (average of Diet 1 and Diet 2).
Diet 4 is from Chan and Carscadden (1976), who examined capelin caught mainly off southern Labrador in August-November 1973. Percentage weights for large zooplankton and small zooplankton were taken from Table 4. The data for the 4 months were averaged, with weightings by monthly stomach fullness (Table 1).
Diet 5 is the average of the spring Grand Bank diet and the autumn Labrador diet (average of Diet 3 and Diet 4)

Appendix 2. Table 13. Diet of sand lance.

	Diet 1
1 Whales	0.000
2 Harp seals	0.000
3 Hooded seals	0.000
4 Seabirds	0.000
5 Cod > 35 cm	0.000
6 Cod <= 35 cm	0.000
7 Greenland halibut > 40 cm	0.000
8 Greenland halibut <= 40 cm	0.000
9 American plaice > 35 cm	0.000
10 American plaice <= 35 cm	0.000
11 Flounders	0.000
12 Skates	0.000
13 Redfish	0.000
14 Demersal feeders (misc. large)	0.000
15 Demersal feeders (misc. small)	0.000
16 Capelin	0.000
17 Sand lance	0.000
18 Arctic cod	0.000
19 Pelagic feeders (misc. large)	0.000
20 Pisc. Pelagic feeders (misc. small)	0.000
21 Plankt. Pelagic feeders (misc. smal	0.000
22 Shrimp	0.000
23 Large Crustaceans (crab, lobster)	0.000
24 Echinoderms	0.000
25 Molluscs (benthic)	0.000
26 Polychaetes	0.000
27 Benthic invertebrates (other)	0.000
28 Zooplankton (large)	0.350
29 Zooplankton (small)	0.650
30 Phytoplankton	0.000
31 Detritus	0.000

Diet information is from Table 1 of Scott (1973). Data (% volume) are from fish collected in May 1967 on the Scotian Shelf.

Appendix 2. Table 14. Diet of Arctic cod.

		Diet 1
1	Whales	0.000
2	Harp seals	0.000
3	Hooded seals	0.000
4	Seabirds	0.000
5	Cod > 35 cm	0.000
6	Cod <= 35 cm	0.000
7	Greenland halibut > 40 cm	0.000
8	Greenland halibut <= 40 cm	0.000
9	American plaice > 35 cm	0.000
10	American plaice <= 35 cm	0.000
11	Flounders	0.000
12	Skates	0.000
13	Redfish	0.000
14	Demersal feeders (misc. large)	0.000
15	Demersal feeders (misc. small)	0.000
16	Capelin	0.038
17	Sand lance	0.000
18	Arctic cod	0.002
19	Pelagic feeders (misc. large)	0.000
20	Pisc. Pelagic feeders (misc. small)	0.000
21	Plankt. Pelagic feeders (misc. small)	0.000
22	Shrimp	0.000
23	Large Crustaceans (crab, lobster)	0.000
24	Echinoderms	0.000
25	Molluscs (benthic)	0.000
26	Polychaetes	0.000
27	Benthic invertebrates (other)	0.000
28	Zooplankton (large)	0.640
29	Zooplankton (small)	0.320
30	Phytoplankton	0.000
31	Detritus	0.000

Diet 1 is a guess based on a small number of observations from northern and southern Labrador in autumn 1978 (Lilly 1980) and additional unreported observations from Divisions 2J, 3K and 3L in autumn 1994.

Appendix 2. Table 15. Diet of large pelagics.

	silver hake		pollock		average
	Diet 1	Diet 1.1	Diet 2	Diet 2.1	Diet 3
1 Whales	0.000	0.000	0.000	0.000	0.000
2 Harp seals	0.000	0.000	0.000	0.000	0.000
3 Hooded seals	0.000	0.000	0.000	0.000	0.000
4 Seabirds	0.000	0.000	0.000	0.000	0.000
5 Cod > 35 cm	0.000	0.000	0.000	0.000	0.000
6 Cod <= 35 cm	0.000	0.000	0.003	0.003	0.002
7 Greenland halibut > 40 cm	0.000	0.000	0.000	0.000	0.000
8 Greenland halibut <= 40 cm	0.000	0.000	0.000	0.000	0.000
9 American plaice > 35 cm	0.000	0.000	0.000	0.000	0.000
10 American plaice <= 35 cm	0.000	0.000	0.000	0.000	0.000
11 Flounders	0.000	0.000	0.000	0.000	0.000
12 Skates	0.000	0.000	0.000	0.000	0.000
13 Redfish	0.000	0.000	0.003	0.003	0.002
14 Demersal feeders (misc. large)	0.000	0.000	0.000	0.000	0.000
15 Demersal feeders (misc. small)	0.070	0.070	0.000	0.000	0.035
16 Capelin	0.000	0.050	0.000	0.100	0.075
17 Sand lance	0.000	0.050	0.322	0.122	0.086
18 Arctic cod	0.000	0.000	0.000	0.000	0.000
19 Pelagic feeders (misc. large)	0.000	0.000	0.000	0.000	0.000
20 Pisc. Pelagic feeders (misc. small)	0.390	0.340	0.156	0.206	0.273
21 Plankt. Pelagic feeders (misc. sma	0.220	0.170	0.155	0.205	0.188
22 Shrimp	0.020	0.020	0.003	0.003	0.012
23 Large Crustaceans (crab, lobster)	0.000	0.000	0.000	0.000	0.000
24 Echinoderms	0.000	0.000	0.000	0.000	0.000
25 Molluscs (benthic)	0.000	0.000	0.000	0.000	0.000
26 Polychaetes	0.005	0.005	0.000	0.000	0.003
27 Benthic invertebrates (other)	0.003	0.003	0.035	0.035	0.019
28 Zooplankton (large)	0.284	0.274	0.316	0.316	0.295
29 Zooplankton (small)	0.000	0.018	0.000	0.007	0.013
30 Phytoplankton	0.000	0.000	0.000	0.000	0.000
31 Detritus	0.000	0.000	0.000	0.000	0.000
Total	0.992	1.000	0.993	1.000	1.000

Diet 1 is from Table 7 of Vinogradov (1983). Data (% weight) are from fish collected in 1968-1974 on Georges Bank.

The demersal feeders (small) are comprised of 0.036 juvenile demersal feeders (large) and 0.034 demersal feeders (small).

Diet 1.1 is a guess. It is Diet 1 modified to take account of diet information in Vinogradov (1972) and Swan and Clay (1979), and the prey suite potentially available on Grand Bank.

A value of 0.05 is subtracted from each of "pisc. pelagic feeders" and "plankt. pelagic feeders" and given to capelin and sand lance. In addition, a value of 0.01 is deducted from "zooplankton (large)" and given to "zooplankton (small)". The 0.008 missing from Diet 1 is also given to "zooplankton (small)".

Diet 2 is from Table 13 of Steele (1963). Data (% volume) are from fish collected on the Scotian Shelf in July 1959 and April-May 1961. The diets of the 3 size-groups in the 1959 sample were averaged without weighting as were the diets of the 4 size-groups in the 1961 sample.The diets from the 2 years were then averaged.

Diet 2.1 is a guess. It is Diet 2 modified to take into account the prey suite potentially available on Grand Bank. A value of 0.2 is subtracted from "sand lance" and given to capelin (0.1), "pisc. pelagic feeders (small)" (0.05) and "plankt. pelagic feeders (small)" (0.05) . A value of 0.1 is subtracted from "pelagic feeders (large)" and given to "demersal feeders large". The 0.007 missing from Diet 2 is given to "zooplankton (small)".

Diet 3 is the diet for large pelagic feeders. It is an average of Diet 1.1 and Diet 2.1

Appendix 2. Table 16. Diet of piscivorous small pelagics.

	mackerel	mesopelagics	short-finned squid		average
	Diet 1	Diet 2	Diet 3	Diet 3.1	Diet 4
1 Whales	0.000	0.000	0.000	0.000	0.000
2 Harp seals	0.000	0.000	0.000	0.000	0.000
3 Hooded seals	0.000	0.000	0.000	0.000	0.000
4 Seabirds	0.000	0.000	0.000	0.000	0.000
5 Cod > 35 cm	0.000	0.000	0.000	0.000	0.000
6 Cod <= 35 cm	0.000	0.000	0.429	0.215	0.019
7 Greenland halibut > 40 cm	0.000	0.000	0.000	0.000	0.000
8 Greenland halibut <= 40 cm	0.000	0.000	0.000	0.000	0.000
9 American plaice > 35 cm	0.000	0.000	0.000	0.000	0.000
10 American plaice <= 35 cm	0.000	0.000	0.000	0.000	0.000
11 Flounders	0.000	0.000	0.000	0.000	0.000
12 Skates	0.000	0.000	0.000	0.000	0.000
13 Redfish	0.000	0.000	0.000	0.000	0.000
14 Demersal feeders (misc. large)	0.000	0.000	0.000	0.000	0.000
15 Demersal feeders (misc. small)	0.000	0.000	0.001	0.001	0.000
16 Capelin	0.810	0.000	0.189	0.359	0.698
17 Sand lance	0.000	0.000	0.252	0.126	0.011
18 Arctic cod	0.000	0.000	0.003	0.003	0.000
19 Pelagic feeders (misc. large)	0.000	0.000	0.000	0.000	0.000
20 Pisc. Pelagic feeders (misc. small	0.000	0.000	0.000	0.000	0.000
21 Plankt. Pelagic feeders (misc. sm	0.000	0.810	0.116	0.116	0.083
22 Shrimp	0.000	0.090	0.000	0.000	0.008
23 Large Crustaceans (crab, lobster)	0.000	0.000	0.000	0.000	0.000
24 Echinoderms	0.000	0.000	0.000	0.000	0.000
25 Molluscs (benthic)	0.000	0.000	0.000	0.000	0.000
26 Polychaetes	0.000	0.000	0.000	0.000	0.000
27 Benthic invertebrates (other)	0.000	0.000	0.000	0.000	0.000
28 Zooplankton (large)	0.180	0.050	0.010	0.180	0.168
29 Zooplankton (small)	0.010	0.050	0.000	0.000	0.013
30 Phytoplankton	0.000	0.000	0.000	0.000	0.000
31 Detritus	0.000	0.000	0.000	0.000	0.000

Diet 1 is from Table 9 of Moores et al. (1979). Data (% occurrence) are from fish collected from commercial catches in Newfoundland waters in June-October (presumably in 1970-1973). The sample size was small.

Diet 2 is a guess based on Podrazhanskaya (1993) and Gartner et al. (1997)

Diet 3 is based on sampling of short-finned squid in inshore waters of eastern Newfoundland in 1985 and 1987. Proportions of fish, crustacea (assumed to be large zooplankters) and squid in the diet were calculated as an average of the values for Holyrood in August and September, 1985 (Table 2 of Dawe (1988)). The fish component was apportioned according to the percentage of identified otoliths in samples from Holyrood and St. Chad's in 1985 and Leading Tickles in 1987 (Table 3 in Dawe et al. (1997)).

Diet 3.1 is an arbitrary adjustment based on assumption that the time and location of sampling might cause underestimation of the importance of crustacean zooplankters and capelin. The values for Atlantic cod and sand lance are arbitrarily reduced by 50%, and the difference (0.340) is arbitrarily assigned equally to large zooplankton and capelin.

Diet 4 is an average diet for piscivorous small pelagics. It is the average of Diets 1, 2 and 3.1, weighted by 0.822, 0.089 and 0.089. These are the proportional biomasses, where the biomass of mackerel is 184411 t and the biomass of the mesopleagics is 20,000 t and the biomass of squid is 20,000 t.

Appendix 2. Table 17. Diet of planktivorous small pelagics.

	herring Diet 1	mesopelagics + Arctic squid Diet 2	average Diet 3
1 Whales	0.000	0.000	0.000
2 Harp seals	0.000	0.000	0.000
3 Hooded seals	0.000	0.000	0.000
4 Seabirds	0.000	0.000	0.000
5 Cod > 35 cm	0.000	0.000	0.000
6 Cod <= 35 cm	0.000	0.000	0.000
7 Greenland halibut > 40 cm	0.000	0.000	0.000
8 Greenland halibut <= 40 cm	0.000	0.000	0.000
9 American plaice > 35 cm	0.000	0.000	0.000
10 American plaice <= 35 cm	0.000	0.000	0.000
11 Flounders	0.000	0.000	0.000
12 Skates	0.000	0.000	0.000
13 Redfish	0.000	0.000	0.000
14 Demersal feeders (misc. large)	0.000	0.000	0.000
15 Demersal feeders (misc. small)	0.000	0.000	0.000
16 Capelin	0.000	0.000	0.000
17 Sand lance	0.000	0.000	0.000
18 Arctic cod	0.000	0.000	0.000
19 Pelagic feeders (misc. large)	0.000	0.000	0.000
20 Pisc. Pelagic feeders (misc. small)	0.000	0.000	0.000
21 Plankt. Pelagic feeders (misc. small)	0.000	0.000	0.000
22 Shrimp	0.000	0.010	0.005
23 Large Crustaceans (crab, lobster)	0.000	0.000	0.000
24 Echinoderms	0.000	0.000	0.000
25 Molluscs (benthic)	0.000	0.000	0.000
26 Polychaetes	0.000	0.000	0.000
27 Benthic invertebrates (other)	0.100	0.000	0.050
28 Zooplankton (large)	0.513	0.540	0.527
29 Zooplankton (small)	0.387	0.450	0.419
30 Phytoplankton	0.000	0.000	0.000
31 Detritus	0.000	0.000	0.000

Diet 1 is from Table 4 of Messieh et al. (1979). Data (significance index) are from fish collected from commerc catches in the Gulf of St. Lawrence and adjacent areas in 1970-1973. The values in Table 4 were summed ov all areas and months, and the sum for each prey category was expressed as a proportion of the sum for all pre categories combined.

Diet 2 is a guess based on Podrazhanskaya (1993) and Gartner et al. (1997) and the assumption that myctophids and other planktivores comprise most of the biomass.

It is assumed here that the diet of Arctic squid is similar to the mesopelagic diet.

Diet 3 is an average diet for planktivorous small pelagics. It is the average of Diets 1 and 2, equally weighted.

Appendix 2. Table 18. Revised diet of the Large Crustacea.

	Original Diet	Revised Diet
1. Whales	0.000	0.000
2. Harp Seals	0.000	0.000
3. Hooded Seals	0.000	0.000
4. Seabirds	0.000	0.000
5. Cod > 35cm	0.000	0.000
6. Cod <= 35 cm	0.000	0.000
7. G.halibut>40cm	0.000	0.000
8. G.halibut<=40cm	0.000	0.000
9. Aplaice>35cm	0.000	0.000
10. Aplaice<=35cm	0.000	0.000
11. Flounders	0.000	0.000
12. Skates	0.000	0.000
13. Redfish	0.000	0.000
14. L.Dem.Feeders	0.000	0.000
15. S.Dem.Feeders	0.050	0.000
16. Capelin	0.000	0.000
17. Sand lance	0.000	0.000
18. Arctic cod	0.000	0.000
19. L.Pel.Feeders	0.000	0.000
20. Pisc. SPF	0.000	0.000
21. Plankt. SPF	0.000	0.000
22. Shrimp	0.049	0.020
23. Large Crustacea	0.111	0.010
24. Echinoderms	0.200	0.300
25. Molluscs	0.198	0.120
26. Polychaetes	0.196	0.300
27. O.Benthic Inver	0.001	0.120
28. L.Zooplankton	0.049	0.020
29. S.Zooplankton	0.049	0.010
30. Phytoplankton	0.000	0.000
31. Detritus	0.097	0.100

Appendix 3 Table 1. Results of the Sensitivity Analysis - Model 1.

			% change in input parameter										
Input parameters		Estimated parameter	-50	-40	-30	-20	-10	0	10	20	30	40	50
1B	1QB	6 B	-0.07	-0.05	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.05	0.07
1B	1QB	14EE	-0.33	-0.26	-0.2	-0.13	-0.07	0	0.07	0.13	0.2	0.26	0.33
1B	1QB	16B	-0.09	-0.07	-0.05	-0.04	-0.02	0	0.02	0.04	0.05	0.07	0.09
1B	1QB	17B	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
1B	1QB	20B	-0.28	-0.22	-0.17	-0.11	-0.06	0	0.06	0.11	0.17	0.22	0.28
1B	1QB	21B	-0.06	-0.05	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.05	0.06
1B	1QB	28B	-0.07	-0.05	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.05	0.07
1B	1QB	29B	-0.07	-0.06	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.06	0.07
1B	1QB	30EE	-0.07	-0.05	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.05	0.07
2B	2PB	2EE	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
2B	2QB	6 B	-0.13	-0.1	-0.08	-0.05	-0.03	0	0.03	0.05	0.08	0.1	0.13
2B	2QB	7EE	-0.1	-0.08	-0.06	-0.04	-0.02	0	0.02	0.04	0.06	0.08	0.1
2B	2QB	8B	-0.18	-0.14	-0.11	-0.07	-0.04	0	0.04	0.07	0.11	0.14	0.18
2B	2QB	10EE	-0.06	-0.05	-0.04	-0.02	-0.01	0	0.01	0.02	0.04	0.05	0.06
2B	2QB	11 B	-0.2	-0.16	-0.12	-0.08	-0.04	0	0.04	0.08	0.12	0.16	0.2
2B	2QB	15 B	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
2B	2QB	16B	-0.09	-0.07	-0.05	-0.04	-0.02	0	0.02	0.04	0.05	0.07	0.09
2B	2QB	17B	-0.08	-0.07	-0.05	-0.03	-0.02	0	0.02	0.03	0.05	0.07	0.08
2B	2QB	18B	-0.33	-0.27	-0.2	-0.13	-0.07	0	0.07	0.13	0.2	0.27	0.33
2B	2QB	19B	-0.15	-0.12	-0.09	-0.06	-0.03	0	0.03	0.06	0.09	0.12	0.15
2B	2QB	20B	-0.1	-0.08	-0.06	-0.04	-0.02	0	0.02	0.04	0.06	0.08	0.1
2B	2QB	21B	-0.07	-0.06	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.06	0.07
2B	2QB	22B	-0.06	-0.05	-0.04	-0.02	-0.01	0	0.01	0.02	0.04	0.05	0.06
2B	2QB	26EE	-0.07	-0.06	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.06	0.07
2B	2QB	27EE	-0.08	-0.06	-0.05	-0.03	-0.02	0	0.02	0.03	0.05	0.06	0.08
2B	2QB	28B	-0.11	-0.08	-0.06	-0.04	-0.02	0	0.02	0.04	0.06	0.08	0.11
2B	2QB	29B	-0.1	-0.08	-0.06	-0.04	-0.02	0	0.02	0.04	0.06	0.08	0.1
2B	2QB	30EE	-0.1	-0.08	-0.06	-0.04	-0.02	0	0.02	0.04	0.06	0.08	0.1
3B	3QB	7EE	-0.13	-0.1	-0.08	-0.05	-0.03	0	0.03	0.05	0.08	0.1	0.13
3B	3QB	8B	-0.16	-0.13	-0.1	-0.06	-0.03	0	0.03	0.06	0.1	0.13	0.16
3B	3QB	11 B	-0.12	-0.1	-0.07	-0.05	-0.02	0	0.02	0.05	0.07	0.1	0.12
3B	3QB	21B	-0.04	-0.03	-0.02	-0.01	-0.01	0	0.01	0.01	0.02	0.03	0.04
3B	3QB	26EE	-0.04	-0.03	-0.02	-0.01	-0.01	0	0.01	0.01	0.02	0.03	0.04
3B	3QB	27EE	-0.03	-0.03	-0.02	-0.01	-0.01	0	0.01	0.01	0.02	0.03	0.03
4B	4QB	QEE	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
5B	5PB	5EE	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
5B	5QB	6 B	-0.13	-0.1	-0.08	-0.05	-0.03	0	0.03	0.05	0.08	0.1	0.13
5B	5QB	8 B	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
5B	5QB	10EE	-0.22	-0.17	-0.13	-0.09	-0.04	0	0.04	0.09	0.13	0.17	0.22
5B	5QB	13B	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
5B	5QB	15 B	-0.15	-0.12	-0.09	-0.06	-0.03	0	0.03	0.06	0.09	0.12	0.15
5B	5QB	16B	-0.16	-0.13	-0.1	-0.06	-0.03	0	0.03	0.06	0.1	0.13	0.16
5B	5QB	17B	-0.16	-0.13	-0.1	-0.06	-0.03	0	0.03	0.06	0.1	0.13	0.16
5B	5QB	18 B	-0.08	-0.07	-0.05	-0.03	-0.02	0	0.02	0.03	0.05	0.07	0.08
5B	5QB	21B	-0.04	-0.03	-0.02	-0.01	-0.01	0	0.01	0.01	0.02	0.03	0.04
5B	5QB	22B	-0.15	-0.12	-0.09	-0.06	-0.03	0	0.03	0.06	0.09	0.12	0.15
5B	5QB	23B	-0.16	-0.13	-0.1	-0.06	-0.03	0	0.03	0.06	0.1	0.13	0.16

5B	5QB	24EE	-0.12	-0.1	-0.07	-0.05	-0.02	0	0.02	0.05	0.07	0.1	0.12
5B	5QB	25EE	-0.15	-0.12	-0.09	-0.06	-0.03	0	0.03	0.06	0.09	0.12	0.15
5B	5QB	26EE	-0.11	-0.09	-0.06	-0.04	-0.02	0	0.02	0.04	0.06	0.09	0.11
5B	5QB	27EE	-0.1	-0.08	-0.06	-0.04	-0.02	0	0.02	0.04	0.06	0.08	0.1
5B	5QB	28B	-0.13	-0.1	-0.08	-0.05	-0.03	0	0.03	0.05	0.08	0.1	0.13
5B	5QB	29B	-0.13	-0.1	-0.08	-0.05	-0.03	0	0.03	0.05	0.08	0.1	0.13
5B	5QB	30EE	-0.13	-0.1	-0.08	-0.05	-0.03	0	0.03	0.05	0.08	0.1	0.13
6 PB	6 EE	6 B	1.06	0.7	0.45	0.26	0.11	0	-0.09	-0.17	-0.24	-0.29	-0.34
6 PB	6 EE	16 B	0.07	0.05	0.03	0.02	0.01	0	-0.01	-0.01	-0.02	-0.02	-0.02
6 PB	6 EE	18 B	0.06	0.04	0.03	0.02	0.01	0	-0.01	-0.01	-0.01	-0.02	-0.02
6 PB	6 EE	22 B	0.11	0.07	0.05	0.03	0.01	0	-0.01	-0.02	-0.02	-0.03	-0.03
6 PB	6 EE	27 EE	0.07	0.05	0.03	0.02	0.01	0	-0.01	-0.01	-0.02	-0.02	-0.02
6 PB	6 EE	28 B	0.06	0.04	0.03	0.02	0.01	0	-0.01	-0.01	-0.01	-0.02	-0.02
6 PB	6 EE	29 B	0.06	0.04	0.03	0.02	0.01	0	-0.01	-0.01	-0.01	-0.02	-0.02
6 PB	6 EE	30 EE	0.06	0.04	0.03	0.02	0.01	0	-0.01	-0.01	-0.01	-0.02	-0.02
6 QB	6 EE	16 B	-0.03	-0.03	-0.02	-0.01	-0.01	0	0.01	0.01	0.02	0.03	0.03
6 QB	6 EE	22 B	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
6 QB	6 EE	27 EE	-0.03	-0.03	-0.02	-0.01	-0.01	0	0.01	0.01	0.02	0.03	0.03
7B		6 B	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
7B	7PB	7EE	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
7B	7QB	8 B	-0.08	-0.06	-0.05	-0.03	-0.02	0	0.02	0.03	0.05	0.06	0.08
7B	7QB	13B	-0.12	-0.09	-0.07	-0.05	-0.02	0	0.02	0.05	0.07	0.09	0.12
7B	7QB	19B	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
7B	7QB	21B	-0.07	-0.05	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.05	0.07
8PB	8 EE	8 B	1.06	0.7	0.45	0.26	0.11	0	-0.09	-0.17	-0.24	-0.29	-0.34
8 PB	8 EE	16B	0.15	0.1	0.06	0.04	0.02	0	-0.01	-0.02	-0.03	-0.04	-0.05
8 PB	8 EE	18 B	0.1	0.07	0.04	0.03	0.01	0	-0.01	-0.02	-0.02	-0.03	-0.03
8 PB	8 EE	28B	0.09	0.06	0.04	0.02	0.01	0	-0.01	-0.02	-0.02	-0.03	-0.03
8 PB	8 EE	29B	0.1	0.06	0.04	0.03	0.01	0	-0.01	-0.02	-0.02	-0.03	-0.03
8 PB	8 EE	30EE	0.1	0.06	0.04	0.03	0.01	0	-0.01	-0.02	-0.02	-0.03	-0.03
8QB		16B	-0.07	-0.05	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.05	0.07
8QB		18 B	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
8QB		28B	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
8QB		29B	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
8QB		30EE	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
9B	9PB	9EE	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
9B	9QB	17B	-0.06	-0.05	-0.04	-0.02	-0.01	0	0.01	0.02	0.04	0.05	0.06
9B	9QB	23B	-0.04	-0.03	-0.02	-0.02	-0.01	0	0.01	0.02	0.02	0.03	0.04
9B	9QB	24EE	-0.07	-0.05	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.05	0.07
9B	9QB	25EE	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
10B		10EE	0.76	0.51	0.33	0.19	-0.08	0	-0.07	-0.13	-0.18	-0.22	-0.25
10QB		10EE	-0.12	-0.09	-0.07	-0.05	-0.02	0	0.02	0.05	0.07	0.09	0.12
10B	10QB	16B	-0.04	-0.03	-0.02	-0.01	-0.01	0	0.01	0.01	0.02	0.03	0.04
10B	10QB	17B	-0.06	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.06
10B	10QB	24EE	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
10B	10QB	25EE	-0.04	-0.03	-0.02	-0.01	-0.01	0	0.01	0.01	0.02	0.03	0.04
10B	10QB	26EE	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
10B	10QB	27EE	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
10PB		10EE	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
11PB	11 EE	11 B	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
11PB	11 EE	26EE	0.24	0.16	0.1	0.06	0.03	0	-0.02	-0.04	-0.06	-0.07	-0.08
11PB	11EE	27EE	0.18	0.12	0.08	0.04	0.02	0	-0.02	-0.03	-0.04	-0.05	-0.06

11QB		26EE	-0.12	-0.09	-0.07	-0.05	-0.02	0	0.02	0.05	0.07	0.09	0.12
11QB		27EE	-0.09	-0.17	-0.05	-0.04	-0.02	0	0.02	0.04	0.05	0.17	0.09
12 B		6B	-0.08	-0.07	-0.05	-0.03	-0.02	0	0.02	0.03	0.05	0.07	0.08
12B	12PB	12EE	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
12B	12QB	13B	-0.11	-0.09	-0.06	-0.04	-0.02	0	0.02	0.04	0.06	0.09	0.11
12B	12QB	15 B	-0.14	-0.11	-0.09	-0.06	-0.03	0	0.03	0.06	0.09	0.11	0.14
12B	12QB	17B	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
12B	12QB	20B	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
12B	12QB	21B	-0.08	-0.06	-0.05	-0.03	-0.01	0	0.01	0.03	0.05	0.06	0.08
12B	12QB	22B	-0.12	-0.1	-0.07	-0.05	-0.02	0	0.02	0.05	0.07	0.1	0.12
12B	12QB	23B	-0.22	-0.18	-0.13	-0.09	-0.04	0	0.04	0.09	0.13	0.18	0.22
12B	12QB	24EE	-0.13	-0.1	-0.08	-0.05	-0.03	0	0.03	0.05	0.08	0.1	0.13
12B	12QB	25EE	-0.13	-0.1	-0.08	-0.05	-0.03	0	0.03	0.05	0.08	0.1	0.13
12B	12QB	26EE	-0.09	-0.07	-0.05	-0.04	-0.02	0	0.02	0.04	0.05	0.07	0.09
12B	12QB	27EE	-0.11	-0.09	-0.06	-0.04	-0.02	0	0.02	0.04	0.06	0.09	0.11
12B	12QB	28EE	-0.04	-0.03	-0.02	-0.02	-0.01	0	0.01	0.02	0.02	0.03	0.04
12B	12QB	29EE	-0.04	-0.03	-0.02	-0.02	-0.01	0	0.01	0.02	0.02	0.03	0.04
12B	12QB	30EE	-0.04	-0.03	-0.02	-0.02	-0.01	0	0.01	0.02	0.02	0.03	0.04
13PB	13EE	13B	1.1	0.72	0.46	0.26	0.12	0	-0.09	-0.17	-0.24	-0.3	-0.34
13PB	13EE	21B	0.6	0.39	0.25	0.14	0.06	0	-0.05	-0.09	-0.13	-0.16	-0.19
13PB	13EE	22B	0.09	0.06	0.04	0.02	0.01	0	-0.01	-0.01	-0.02	-0.02	-0.03
13PB	13EE	28B	0.12	0.08	0.05	0.03	0.01	0	-0.01	-0.02	-0.03	-0.03	-0.04
13PB	13EE	29B	0.11	0.07	0.05	0.03	0.01	0	-0.01	-0.02	-0.02	-0.03	-0.03
13PB	13EE	30EE	0.11	0.07	0.05	0.03	0.01	0	-0.01	-0.02	-0.02	-0.03	-0.03
13QB		21B	-0.28	-0.22	-0.17	-0.11	-0.06	0	0.06	0.11	0.17	0.22	0.28
13QB		22B	-0.04	-0.03	-0.02	-0.02	-0.01	0	0.01	0.02	0.02	0.03	0.04
13QB		28B	-0.06	-0.05	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.05	0.06
13QB		29B	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
13QB		30EE	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
14B	14PB	14 EE	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
14B	14QB	10EE	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
14B	14QB	22 B	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
14B	14QB	24 EE	-0.04	-0.03	-0.02	-0.02	-0.01	0	0.01	0.02	0.02	0.03	0.04
14B	14QB	27 EE	-0.04	-0.03	-0.02	-0.02	-0.01	0	0.01	0.02	0.02	0.03	0.04
15 PB	15 EE	15 B	1.22	0.78	0.49	0.28	0.12	0	-0.1	-0.18	-0.25	-0.31	-0.35
15 PB	15 EE	22B	0.17	0.11	0.07	0.04	0.02	0	-0.01	-0.02	-0.03	-0.04	-0.05
15 PB	15 EE	23B	0.11	0.08	0.05	0.03	0.01	0	-0.01	-0.02	-0.03	-0.03	-0.04
15 PB	15 EE	24EE	0.26	0.17	0.1	0.06	0.03	0	-0.02	-0.04	-0.05	-0.06	-0.07
15 PB	15 EE	25EE	0.33	0.21	0.13	0.08	0.03	0	-0.03	-0.05	-0.07	-0.08	-0.1
15 PB	15 EE	26EE	0.36	0.23	0.15	0.08	0.04	0	-0.03	-0.05	-0.07	-0.09	-0.1
15 PB	15 EE	27EE	0.64	0.41	0.26	0.15	0.07	0	-0.05	-0.1	-0.13	-0.16	-0.19
15QB		15 B	-0.05	-0.04	-0.02	-0.02	-0.01	0	0.01	0.02	0.02	0.04	0.05
15QB		22B	-0.07	-0.05	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.05	0.07
15QB		23B	-0.05	-0.04	-0.02	-0.02	-0.01	0	0.01	0.02	0.02	0.04	0.05
15QB		24EE	-0.11	-0.08	-0.06	-0.04	-0.02	0	0.02	0.04	0.06	0.08	0.11
15QB		25EE	-0.14	-0.11	-0.09	-0.06	-0.03	0	0.03	0.06	0.09	0.11	0.14
15QB		26EE	-0.15	-0.13	-0.09	-0.06	-0.03	0	0.03	0.06	0.09	0.13	0.15
15QB		27EE	-0.28	-0.22	-0.17	-0.11	-0.06	0	0.06	0.11	0.17	0.22	0.28
16PB	16EE	16B	1.09	0.71	0.45	0.26	0.12	0	-0.09	-0.17	-0.23	-0.29	-0.33
16PB	16EE	17B	0.22	0.14	0.09	0.05	0.02	0	-0.02	-0.03	-0.05	-0.06	-0.07
16PB	16EE	28B	0.57	0.37	0.24	0.14	0.06	0	-0.05	-0.09	-0.12	-0.15	-0.18
16PB	16EE	29B	0.58	0.38	0.24	0.14	0.06	0	-0.05	-0.09	-0.13	-0.16	-0.18

16PB	16EE	30EE	0.58	0.38	0.24	0.14	0.06	0	-0.05	-0.09	-0.13	-0.16	-0.18
16QB		17B	-0.1	-0.08	-0.06	-0.04	-0.02	0	0.02	0.04	0.06	0.08	0.1
16QB		28B	-0.27	-0.21	-0.16	-0.11	-0.05	0	0.05	0.11	0.16	0.21	0.27
16QB		29B	-0.27	-0.21	-0.16	-0.11	-0.05	0	0.05	0.11	0.16	0.21	0.27
16QB		30EE	-0.27	-0.21	-0.16	-0.11	-0.05	0	0.05	0.11	0.16	0.21	0.27
17PB	17EE	17B	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
17PB	17EE	28B	0.14	0.09	0.06	0.04	0.02	0	-0.01	-0.02	-0.03	-0.04	-0.05
17PB	17EE	29B	0.16	0.11	0.07	0.04	0.02	0	-0.01	-0.03	-0.04	-0.05	-0.05
17PB	17EE	30EE	0.16	0.11	0.07	0.04	0.02	0	-0.01	-0.03	-0.04	-0.04	-0.05
17QB		28B	-0.07	-0.06	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.06	0.07
17QB		29B	-0.08	-0.06	-0.05	-0.03	-0.02	0	0.02	0.03	0.05	0.06	0.08
17QB		30EE	-0.08	-0.06	-0.05	-0.03	-0.02	0	0.02	0.03	0.05	0.06	0.08
18PB	18EE	18 B	1.03	0.68	0.44	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.34
18B	18EE	28B	0.11	0.08	0.05	0.03	0.01	0	-0.01	-0.02	-0.03	-0.03	-0.04
18B	18EE	29B	0.1	0.07	0.04	0.03	0.01	0	-0.01	-0.02	-0.02	-0.03	-0.03
18B	18EE	30EE	0.1	0.07	0.04	0.03	0.01	0	-0.01	-0.02	-0.02	-0.03	-0.03
18QB			-0.06	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.06
18QB			-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
18QB			-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
19PB	19EE	19B	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
20PB	20EE	6 B	0.1	0.07	0.04	0.03	0.01	0	-0.01	-0.02	-0.02	-0.03	-0.03
20PB	20EE	16B	0.14	0.09	0.06	0.03	0.01	0	-0.01	-0.02	-0.03	-0.04	-0.05
20PB	20EE	20B	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
20PB	20EE	21B	0.13	0.09	0.06	0.03	0.01	0	-0.01	-0.02	-0.03	-0.04	-0.04
20PB	20EE	28B	0.1	0.07	0.04	0.02	0.01	0	-0.01	-0.02	-0.02	-0.03	-0.03
20PB	20EE	29B	0.1	0.07	0.04	0.02	0.01	0	-0.01	-0.02	-0.02	-0.03	-0.03
20PB	20EE	30EE	0.1	0.07	0.04	0.02	0.01	0	-0.01	-0.02	-0.02	-0.03	-0.03
20QB		6 B	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
20QB		16B	-0.07	-0.06	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.06	0.07
20QB		21B	-0.07	-0.06	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.06	0.07
20QB		28B	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
20QB		29B	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
20QB		30EE	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
21PB	21EE	21B	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
21PB	21EE	27EE	0.07	0.05	0.03	0.02	0.01	0	-0.01	-0.01	-0.02	-0.02	-0.02
21PB	21EE	28B	0.12	0.08	0.05	0.03	0.01	0	-0.01	-0.02	-0.03	-0.04	-0.04
21PB	21EE	29B	0.11	0.08	0.05	0.03	0.01	0	-0.01	-0.02	-0.03	-0.03	-0.04
21PB	21EE	30EE	0.12	0.08	0.05	0.03	0.01	0	-0.01	-0.02	-0.03	-0.03	-0.04
21QB		27EE	-0.04	-0.03	-0.02	-0.02	-0.01	0	0.01	0.02	0.02	0.03	0.04
21QB		28B	-0.06	-0.05	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.05	0.06
21QB		29B	-0.06	-0.05	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.05	0.06
21QB		30EE	-0.06	-0.05	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.05	0.06
22PB	22EE	22B	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
23PB		15 B	0.63	0.39	0.24	0.13	0.06	0	-0.05	-0.08	-0.11	-0.14	-0.16
23PB		22B	0.62	0.38	0.24	0.13	0.06	0	-0.05	-0.08	-0.11	-0.14	-0.16
23PB		23B	1.45	0.9	0.55	0.31	0.13	0	-0.11	-0.19	-0.26	-0.32	-0.37
23PB		24EE	1	0.62	0.38	0.21	0.09	0	-0.07	-0.13	-0.18	-0.22	-0.26
23PB		25EE	1.07	0.67	0.41	0.23	0.1	0	-0.08	-0.14	-0.19	-0.24	-0.27
23PB		26EE	0.75	0.46	0.28	0.16	0.07	0	-0.05	-0.1	-0.13	-0.16	-0.19
23PB		27EE	0.46	0.28	0.17	0.1	0.04	0	-0.03	-0.06	-0.08	-0.1	-0.12
23QB		15 B	-0.23	-0.19	-0.15	-0.1	-0.05	0	0.05	0.1	0.15	0.19	0.23
23QB		22B	-0.23	-0.19	-0.14	-0.1	-0.05	0	0.05	0.1	0.14	0.19	0.23

23QB		23B	-0.08	-0.07	-0.05	-0.04	-0.02	0	0.02	0.04	0.05	0.07	0.08
23QB		24EE	-0.37	-0.3	-0.23	-0.16	-0.08	0	0.08	0.15	0.22	0.3	0.38
23QB		25EE	-0.4	-0.33	-0.25	-0.17	-0.09	0	0.09	0.15	0.23	0.31	0.4
23QB		26EE	-0.28	-0.23	-0.17	-0.12	-0.06	0	0.06	0.12	0.14	0.19	0.25
23QB		27EE	-0.17	-0.14	-0.11	-0.07	-0.04	0	0.01	0.02	0.03	0.04	0.06
24 B	24 PB	24 Ee	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
25 B	25 PB	25 Ee	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
26 B	26 PB	26 Ee	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
27 B	27 PB	27 Ee	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
28PB	28EE	28B	2.49	1.33	0.75	0.4	0.17	0	-0.12	-0.22	-0.3	-0.36	-0.42
28PB	28EE	29B	1.95	1.04	0.59	0.31	0.13	0	-0.1	-0.17	-0.23	-0.28	-0.33
28PB	28EE	30EE	2.05	1.09	0.62	0.33	0.14	0	-0.1	-0.18	-0.25	-0.3	-0.34
28QB		28B	-0.18	-0.15	-0.11	-0.08	-0.04	0	0.04	0.09	0.15	0.21	0.27
28QB		29B	-0.46	-0.38	-0.3	-0.21	-0.11	0	0.12	0.24	0.38	0.54	0.71
28QB		30EE	-0.48	-0.4	-0.31	-0.22	-0.11	0	0.12	0.26	0.4	0.57	0.75
29PB	29EE	29B	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
29PB	29EE	30EE	0.81	0.54	0.35	0.2	0.09	0	-0.07	-0.13	-0.19	-0.23	-0.27
29QB		30EE	-0.4	-0.32	-0.24	-0.16	-0.08	0	0.08	0.16	0.24	0.32	0.4
30B		30EE	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33

Appendix 3 Table 2. Results of the Sensitivity Analysis - Model 2.

Input parameters		Estimated parameter	% change in input parameter										
			-50	-40	-30	-20	-10	0	10	20	30	40	50
1B	1QB	6B	-0.08	-0.06	-0.05	-0.03	-0.02	0	0.02	0.03	0.05	0.06	0.08
1B	1QB	14EE	-0.33	-0.26	-0.2	-0.13	-0.07	0	0.07	0.13	0.2	0.26	0.33
1B	1QB	15B	-0.06	-0.05	-0.04	-0.02	-0.01	0	0.01	0.02	0.04	0.05	0.06
1B	1QB	16B	-0.09	-0.07	-0.05	-0.04	-0.02	0	0.02	0.04	0.05	0.07	0.09
1B	1QB	17B	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
1B	1QB	20B	-0.28	-0.22	-0.17	-0.11	-0.06	0	0.06	0.11	0.17	0.22	0.28
1B	1QB	21B	-0.06	-0.05	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.05	0.06
1B	1QB	28B	-0.06	-0.05	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.05	0.06
1B	1QB	29B	-0.06	-0.05	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.05	0.06
1B	1QB	30EE	-0.06	-0.05	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.05	0.06
2B	2PB	2EE	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
2B	2QB	6B	-0.16	-0.13	-0.09	-0.06	-0.03	0	0.03	0.06	0.09	0.13	0.16
2B	2QB	7EE	-0.1	-0.08	-0.06	-0.04	-0.02	0	0.02	0.04	0.06	0.08	0.1
2B	2QB	8B	-0.18	-0.14	-0.11	-0.07	-0.04	0	0.04	0.07	0.11	0.14	0.18
2B	2QB	10EE	-0.06	-0.05	-0.04	-0.02	-0.01	0	0.01	0.02	0.04	0.05	0.06
2B	2QB	11B	-0.2	-0.16	-0.12	-0.08	-0.04	0	0.04	0.08	0.12	0.16	0.2
2B	2QB	15B	-0.11	-0.09	-0.06	-0.04	-0.02	0	0.02	0.04	0.06	0.09	0.11
2B	2QB	16 EE	-0.1	-0.08	-0.06	-0.04	-0.02	0	0.02	0.04	0.06	0.08	0.1
2B	2QB	17B	-0.08	-0.06	-0.05	-0.03	-0.02	0	0.02	0.03	0.05	0.06	0.08
2B	2QB	18B	-0.36	-0.29	-0.22	-0.14	-0.07	0	0.07	0.14	0.22	0.29	0.36
2B	2QB	19B	-0.15	-0.12	-0.09	-0.06	-0.03	0	0.03	0.06	0.09	0.12	0.15
2B	2QB	20B	-0.1	-0.08	-0.06	-0.04	-0.02	0	0.02	0.04	0.06	0.08	0.1
2B	2QB	21B	-0.08	-0.06	-0.05	-0.03	-0.02	0	0.02	0.03	0.05	0.06	0.08
2B	2QB	22 B	-0.1	-0.08	-0.06	-0.04	-0.02	0	0.02	0.04	0.06	0.08	0.1
2B	2QB	25 EE	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
2B	2QB	26 EE	-0.09	-0.07	-0.05	-0.04	-0.02	0	0.02	0.04	0.05	0.07	0.09
2B	2QB	27 EE	-0.1	-0.08	-0.06	-0.04	-0.02	0	0.02	0.04	0.06	0.08	0.1
2B	2QB	28B	-0.06	-0.05	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.05	0.06
2B	2QB	29B	-0.06	-0.05	-0.04	-0.02	-0.01	0	0.01	0.02	0.04	0.05	0.06
2B	2QB	30EE	-0.06	-0.05	-0.04	-0.02	-0.01	0	0.01	0.02	0.04	0.05	0.06
3B	3QB	7EE	-0.13	-0.1	-0.08	-0.05	-0.03	0	0.03	0.05	0.08	0.1	0.13
3B	3QB	8 B	-0.16	-0.13	-0.1	-0.06	-0.03	0	0.03	0.06	0.1	0.13	0.16
3B	3QB	11B	-0.12	-0.1	-0.07	-0.05	-0.02	0	0.02	0.05	0.07	0.1	0.12
3B	3QB	15 B	-0.04	-0.03	-0.02	-0.02	-0.01	0	0.01	0.02	0.02	0.03	0.04
3B	3QB	21 B	-0.04	-0.03	-0.02	-0.02	-0.01	0	0.01	0.02	0.02	0.03	0.04
3B	3QB	26 EE	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
3B	3QB	27 EE	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
4B	4PB	4EE	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
5B	5PB	5EE	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
5B	5PB	6 B	-0.1	-0.08	-0.06	-0.04	-0.02	0	0.02	0.04	0.06	0.08	0.1
5B	5QB	8 B	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
5B	5QB	10EE	-0.17	-0.14	-0.1	-0.07	-0.03	0	0.03	0.07	0.1	0.14	0.17
5B	5QB	13B	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
5B	5QB	15 B	-0.11	-0.09	-0.07	-0.04	-0.02	0	0.02	0.04	0.07	0.09	0.11
5B	5QB	16EE	-0.12	-0.09	-0.07	-0.05	-0.02	0	0.02	0.05	0.07	0.09	0.12
5B	5QB	17B	-0.1	-0.08	-0.06	-0.04	-0.02	0	0.02	0.04	0.06	0.08	0.1
5B	5QB	18 B	-0.06	-0.05	-0.04	-0.02	-0.01	0	0.01	0.02	0.04	0.05	0.06

5B	5QB	22B	-0.12	-0.1	-0.07	-0.05	-0.02	0	0.02	0.05	0.07	0.1	0.12
5B	5QB	23B	-0.18	-0.14	-0.11	-0.07	-0.04	0	0.04	0.07	0.11	0.14	0.18
5B	5QB	24EE	-0.11	-0.09	-0.06	-0.04	-0.02	0	0.02	0.04	0.06	0.09	0.11
5B	5QB	25EE	-0.13	-0.1	-0.08	-0.05	-0.03	0	0.03	0.05	0.08	0.1	0.13
5B	5QB	26EE	-0.09	-0.07	-0.05	-0.04	-0.02	0	0.02	0.04	0.05	0.07	0.09
6PB	6EE	6B	1.06	0.7	0.45	0.26	0.11	0	-0.09	-0.17	-0.24	-0.29	-0.34
6PB	6EE	16 EE	0.06	0.04	0.03	0.02	0.01	0	-0.01	-0.01	-0.01	-0.02	-0.02
6 PB	6EE	22 B	0.14	0.09	0.06	0.03	0.02	0	-0.01	-0.02	-0.03	-0.04	-0.04
6PB	6EE	23 B	0.06	0.04	0.03	0.02	0.01	0	-0.01	-0.01	-0.01	-0.02	-0.02
6PB	6EE	27 EE	0.07	0.05	0.03	0.02	0.01	0	-0.01	-0.01	-0.02	-0.02	-0.02
6 QB		22 B	-0.07	-0.05	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.05	0.07
6 QB		27 EE	-0.03	-0.03	-0.02	-0.01	-0.01	0	0.01	0.01	0.02	0.03	0.03
7B		6B	-0.06	-0.05	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.05	0.06
7B	7PB	7EE	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
7B	7QB	8 B	-0.08	-0.06	-0.05	-0.03	-0.02	0	0.02	0.03	0.05	0.06	0.08
7B	7QB	13B	-0.14	-0.11	-0.08	-0.05	-0.03	0	0.03	0.05	0.08	0.11	0.14
7B	7QB	19B	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
7B	7QB	21B	-0.08	-0.06	-0.05	-0.03	-0.01	0	0.01	0.03	0.05	0.06	0.08
7B	7QB	22B	-0.03	-0.03	-0.02	-0.01	-0.01	0	0.01	0.01	0.02	0.03	0.03
8 PB	8 EE	8B	1.06	0.7	0.45	0.26	0.11	0	-0.09	-0.17	-0.24	-0.29	-0.34
8 PB	8 EE	16 EE	0.15	0.1	0.06	0.04	0.02	0	-0.01	-0.02	-0.03	-0.04	-0.05
8 PB	8 EE	18 B	0.11	0.07	0.05	0.03	0.01	0	-0.01	-0.02	-0.02	-0.03	-0.03
8QB		16 EE	-0.07	-0.05	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.05	0.07
8QB		18 B	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
9B	9PB	9EE	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
9B	9QB	17B	-0.07	-0.05	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.05	0.07
9B	9QB	23B	-0.07	-0.05	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.05	0.07
9B	9QB	24EE	-0.11	-0.09	-0.06	-0.04	-0.02	0	0.02	0.04	0.06	0.09	0.11
9B	9QB	25EE	-0.07	-0.05	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.05	0.07
10B		10EE	0.72	0.48	0.31	0.18	-0.08	0	-0.07	-0.12	-0.17	-0.21	-0.24
10QB		10EE	-0.14	-0.11	-0.08	-0.06	-0.03	0	0.03	0.06	0.08	0.11	0.14
10B	10QB	15B	-0.04	-0.03	-0.02	-0.02	-0.01	0	0.01	0.02	0.02	0.03	0.04
10B	10QB	16 EE	-0.04	-0.03	-0.02	-0.02	-0.01	0	0.01	0.02	0.02	0.03	0.04
10B	10QB	17B	-0.06	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.06
10B	10QB	23 B	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
10B	10QB	24EE	-0.07	-0.05	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.05	0.07
10B	10QB	25EE	-0.06	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.06
10B	10QB	26EE	-0.06	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.06
10B	10QB	27EE	-0.06	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.06
10PB		10EE	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
11PB		11B	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
11PB		25 EE	0.08	0.05	0.03	0.02	0.01	0	-0.01	-0.01	-0.02	-0.02	-0.03
11PB		26EE	0.32	0.21	0.14	0.08	0.04	0	-0.03	-0.05	-0.07	-0.09	-0.11
11PB		27EE	0.24	0.16	0.1	0.06	0.03	0	-0.02	-0.04	-0.06	-0.07	-0.08
11 QB		25 EE	-0.04	-0.03	-0.02	-0.02	-0.01	0	0.01	0.02	0.02	0.03	0.04
11QB		26EE	-0.16	-0.13	-0.1	-0.06	-0.03	0	0.03	0.06	0.1	0.13	0.16
11QB		27EE	-0.12	-0.1	-0.07	-0.05	-0.02	0	0.02	0.05	0.07	0.1	0.12
12 B		6B	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
12B	12PB	12EE	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
12B	12QB	13B	-0.07	-0.05	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.05	0.07
12B	12QB	15 B	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
12B	12QB	21B	-0.04	-0.03	-0.02	-0.02	-0.01	0	0.01	0.02	0.02	0.03	0.04

12B	12QB	22B	-0.04	-0.03	-0.02	-0.02	-0.01	0	0.01	0.02	0.02	0.03	0.04
12B	12QB	23B	-0.13	-0.1	-0.08	-0.05	-0.03	0	0.03	0.05	0.08	0.1	0.13
12B	12QB	24EE	-0.08	-0.06	-0.05	-0.03	-0.01	0	0.01	0.03	0.05	0.06	0.08
12B	12QB	25EE	-0.07	-0.05	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.05	0.07
12B	12QB	26EE	-0.07	-0.05	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.05	0.07
12B	12QB	27 EE	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
13PB	13EE	13B	1.1	0.72	0.46	0.26	0.12	0	-0.09	-0.17	-0.24	-0.3	-0.34
13PB	13EE	21B	0.6	0.39	0.25	0.14	0.06	0	-0.05	-0.09	-0.13	-0.16	-0.19
13PB	13EE	22B	0.14	0.09	0.06	0.03	0.01	0	-0.01	-0.02	-0.03	-0.04	-0.04
13PB	13EE	28B	0.11	0.07	0.05	0.03	0.01	0	-0.01	-0.02	-0.02	-0.03	-0.03
13PB	13EE	29B	0.1	0.07	0.04	0.02	0.01	0	-0.01	-0.02	-0.02	-0.03	-0.03
13PB	13EE	30EE	0.1	0.07	0.04	0.02	0.01	0	-0.01	-0.02	-0.02	-0.03	-0.03
13QB		21B	-0.28	-0.22	-0.17	-0.11	-0.06	0	0.06	0.11	0.17	0.22	0.28
13QB		22B	-0.06	-0.05	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.05	0.06
13QB		28B	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
13QB		29B	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
13QB		30EE	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
14B	14QB	10EE	-0.06	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.06
14B	14PB	14 EE	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
14B	14QB	15 B	-0.04	-0.03	-0.02	-0.02	-0.01	0	0.01	0.02	0.02	0.03	0.04
14B	14QB	22 B	-0.07	-0.05	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.05	0.07
14B	14QB	24 EE	-0.06	-0.05	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.05	0.06
14B	14QB	25 EE	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
14B	14QB	26 EE	-0.04	-0.03	-0.02	-0.02	-0.01	0	0.01	0.02	0.02	0.03	0.04
14B	14QB	27 EE	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
15 PB	15 EE	15 B	1.12	0.73	0.46	0.27	0.12	0	-0.1	-0.17	-0.24	-0.3	-0.35
15 PB	15 EE	22B	0.11	0.07	0.05	0.03	0.01	0	-0.01	-0.02	-0.02	-0.03	-0.03
15 PB	15 EE	23B	0.08	0.05	0.03	0.02	0.01	0	-0.01	-0.01	-0.02	-0.02	-0.03
15 PB	15 EE	24EE	0.17	0.11	0.07	0.04	0.02	0	-0.01	-0.03	-0.04	-0.05	-0.05
15 PB	15 EE	25EE	0.3	0.2	0.13	0.07	0.03	0	-0.03	-0.05	-0.07	-0.08	-0.09
15 PB	15 EE	26EE	0.21	0.14	0.09	0.05	0.02	0	-0.02	-0.03	-0.05	-0.06	-0.07
15 PB	15 EE	27EE	0.39	0.26	0.16	0.09	0.04	0	-0.03	-0.06	-0.08	-0.1	-0.12
15QB		22B	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
15QB		23B	-0.04	-0.03	-0.02	-0.02	-0.01	0	0.01	0.02	0.02	0.03	0.04
15QB		24EE	-0.08	-0.06	-0.05	-0.03	-0.01	0	0.01	0.03	0.05	0.06	0.08
15QB		25EE	-0.14	-0.11	-0.08	-0.05	-0.03	0	0.03	0.05	0.08	0.11	0.14
15QB		26EE	-0.1	-0.08	-0.06	-0.04	-0.02	0	0.02	0.04	0.06	0.08	0.1
15QB		27EE	-0.18	-0.14	-0.11	-0.07	-0.04	0	0.04	0.07	0.11	0.14	0.18
16 B		16 EE	0.96	0.64	0.41	0.24	0.11	0	-0.09	-0.16	-0.22	-0.27	-0.32
16 B	16QB	17B	-0.11	-0.09	-0.07	-0.05	-0.02	0	0.02	0.05	0.07	0.09	0.11
16 B	16QB	28B	-0.28	-0.23	-0.17	-0.11	-0.06	0	0.06	0.11	0.17	0.23	0.28
16 B	16QB	29B	-0.29	-0.23	-0.17	-0.12	-0.06	0	0.06	0.12	0.17	0.23	0.29
16 B	16QB	30EE	-0.29	-0.23	-0.17	-0.12	-0.06	0	0.06	0.12	0.17	0.23	0.29
16 PB		16 EE	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
17PB	17EE	17B	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
17PB	17EE	28B	0.14	0.09	0.06	0.04	0.02	0	-0.01	-0.02	-0.03	-0.04	-0.05
17PB	17EE	29B	0.16	0.11	0.07	0.04	0.02	0	-0.01	-0.03	-0.04	-0.05	-0.05
17PB	17EE	30EE	0.16	0.11	0.07	0.04	0.02	0	-0.01	-0.03	-0.04	-0.04	-0.05
17QB		28B	-0.07	-0.06	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.06	0.07
17QB		29B	-0.08	-0.06	-0.05	-0.03	-0.02	0	0.02	0.03	0.05	0.06	0.08
17QB		30EE	-0.08	-0.06	-0.05	-0.03	-0.02	0	0.02	0.03	0.05	0.06	0.08
18PB	18 EE	18 B	1.03	0.68	0.44	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33

18B	18 EE	28B	0.1	0.07	0.04	0.03	0.01	0	-0.01	-0.02	-0.02	-0.03	-0.03
18B	18 EE	29B	0.09	0.06	0.04	0.02	0.01	0	-0.01	-0.02	-0.02	-0.03	-0.03
18B	18 EE	30EE	0.09	0.06	0.04	0.02	0.01	0	-0.01	-0.02	-0.02	-0.03	-0.03
18QB		28B	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
18QB		29B	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
18QB		30EE	-0.05	-0.04	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.04	0.05
19PB	19EE	19B	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
20PB	20EE	6 B	0.12	0.08	0.05	0.03	0.01	0	-0.01	-0.02	-0.03	-0.03	-0.04
20PB	20EE	16 EE	0.14	0.09	0.06	0.03	0.01	0	-0.01	-0.02	-0.03	-0.04	-0.05
20PB	20EE	20B	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
20PB	20EE	21B	0.13	0.09	0.06	0.03	0.01	0	-0.01	-0.02	-0.03	-0.04	-0.04
20 QB		6 B	-0.06	-0.05	-0.03	-0.02	-0.01	0	0.01	0.02	0.03	0.05	0.06
20QB		16 EE	-0.07	-0.06	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.06	0.07
20QB		21B	-0.07	-0.06	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.06	0.07
21PB	21EE	21B	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
21PB	21EE	27EE	0.09	0.06	0.04	0.02	0.01	0	-0.01	-0.01	-0.02	-0.03	-0.03
21PB	21EE	28B	0.12	0.08	0.05	0.03	0.01	0	-0.01	-0.02	-0.03	-0.04	-0.04
21PB	21EE	29B	0.11	0.08	0.05	0.03	0.01	0	-0.01	-0.02	-0.03	-0.03	-0.04
21PB	21EE	30EE	0.11	0.08	0.05	0.03	0.01	0	-0.01	-0.02	-0.03	-0.03	-0.04
21QB		27EE	-0.04	-0.03	-0.02	-0.02	-0.01	0	0.01	0.02	0.02	0.03	0.04
21QB		28B	-0.06	-0.05	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.05	0.06
21QB		29B	-0.06	-0.05	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.05	0.06
21QB		30EE	-0.06	-0.05	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.05	0.06
22PB	22EE	22B	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
23PB		22B	0.51	0.32	0.2	0.11	0.05	0	-0.04	-0.07	-0.1	-0.12	-0.14
23PB	23 EE	23B	1.26	0.81	0.5	0.29	0.13	0	-0.1	-0.18	-0.25	-0.31	-0.36
23PB	23 EE	24EE	0.69	0.44	0.27	0.16	0.07	0	-0.05	-0.1	-0.14	-0.17	-0.2
23PB	23 EE	25EE	0.58	0.37	0.23	0.13	0.06	0	-0.05	-0.08	-0.12	-0.14	-0.16
23PB	23 EE	26EE	0.5	0.32	0.2	0.11	0.05	0	-0.04	-0.07	-0.1	-0.12	-0.14
23PB	23 EE	27EE	0.2	0.13	0.08	0.05	0.02	0	-0.02	-0.03	-0.04	-0.05	-0.06
23QB		22B	-0.07	-0.06	-0.04	-0.03	-0.02	0	0.02	0.03	0.04	0.06	0.07
23QB		23B	-0.06	-0.05	-0.04	-0.03	-0.01	0	0.01	0.03	0.04	0.05	0.06
23QB		24EE	-0.29	-0.23	-0.18	-0.12	-0.06	0	0.06	0.12	0.18	0.23	0.29
23QB		25EE	-0.24	-0.2	-0.15	-0.1	-0.05	0	0.05	0.1	0.15	0.2	0.24
23QB		26EE	-0.21	-0.17	-0.13	-0.09	-0.04	0	0.04	0.09	0.13	0.17	0.21
23QB		27EE	-0.08	-0.07	-0.05	-0.03	-0.02	0	0.02	0.03	0.05	0.07	0.08
24 B	24 PB	24 EE	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
25 B	25 PB	25 EE	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
26 B	26 PB	26 EE	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
27 B	27 PB	27 EE	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
28PB	28EE	28B	2.49	1.33	0.75	0.4	0.17	0	-0.12	-0.22	-0.3	-0.36	-0.42
28PB	28EE	29B	1.95	1.04	0.59	0.31	0.13	0	-0.1	-0.17	-0.23	-0.28	-0.33
28PB	28EE	30EE	2.05	1.09	0.62	0.33	0.14	0	-0.1	-0.18	-0.25	-0.3	-0.34
28QB		28B	-0.18	-0.15	-0.11	-0.08	-0.04	0	0.04	0.09	0.15	0.21	0.27
28QB		29B	-0.46	-0.38	-0.3	-0.21	-0.11	0	0.12	0.24	0.38	0.54	0.71
28QB		30EE	-0.48	-0.4	-0.31	-0.22	-0.11	0	0.12	0.26	0.4	0.57	0.75
29PB	29EE	29B	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33
29PB	29EE	30EE	0.81	0.54	0.35	0.2	0.09	0	-0.07	-0.13	-0.19	-0.23	-0.27
29QB		30EE	-0.4	-0.32	-0.24	-0.16	-0.08	0	0.08	0.16	0.24	0.32	0.4
30PB	30EE	30B	1	0.67	0.43	0.25	0.11	0	-0.09	-0.17	-0.23	-0.29	-0.33